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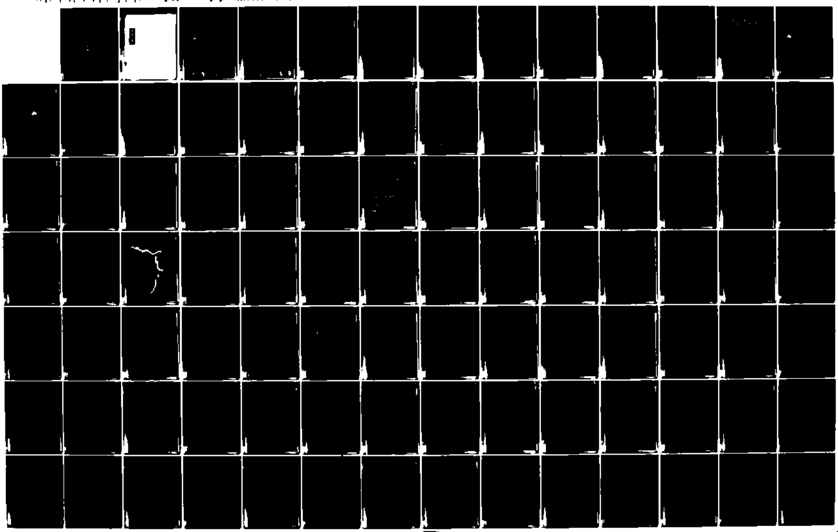

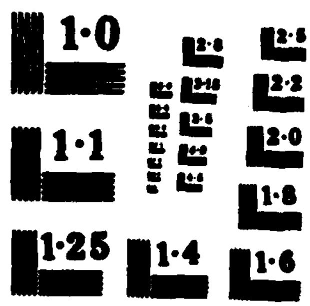
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Goals of the Defense Environmental Program
Peter S. Daley
Presented at the
American Defense Preparedness Association
13th Environmental Systems Symposium
March 20, 1984

Good morning ladies and gentlemen. I am here this morning to tell you about the Defense environmental program and what our goals are. In preparing to talk to you, I asked myself why all you environmental scientists and engineers came here today. The first reason was undoubtedly to ride the Metro now that it's almost reached Bethesda. I came here five years ago for the same reason, and I am still waiting. Maybe by organizing, our dream will be fulfilled. I hope you came here to find out what is going on in the DoD environmental program so you could beter respond to our needs. It is a laudable purpose, and we fully support it. It's certainly one reason I am here. Another reason we are both here is to learn something. We usually call that tech transfer. Heaven knows we all need it. We have plenty of unsolved problems. We don't even know how to define when a problem's been cleared up, and we do lots of reinventing the wheel. We are now embarked on an "innovative" project to do turn-key contractng of waste treatment plants. I use "innovative" here in the very loose sense of the word.

Goals

Let me now respond to the first reason you came -- to hear about our goals. In doing so, I will tell you how we expect to get there, how far we have gotten, and what's coming. It is the goal of the remainder of the conference to cover the tech transfer.

So what is going on? A lot! In case you haven't noticed, we have all been very busy trying to solve problems. We have defined our goals in two simple phrases because I am a firm believer that more than two goals is "no goals." We must maintain our focus. Our two goals are (1) environmental regulatory compliance and (2) waste stream reduction. By compliance we mean complying with all state, local and federal laws and regulations. We also mean achievement of the national goal to expeditiously clean up hazardous waste sites. In our hazardous waste cleanup program, we put a firm deadline on completing our program by 1993. This seems like a long way out, but I know few other organizations that have set any such goals for themselves. In 1980, we established a goal to complete assessment of all defense installation cleanup problems by 1985. We are now nearly 80% of the way to achieving that goal and, because we have contracts in place to do the rest of the work, we are virtually assured of reaching it.

Compliance

Why should we be so interested in compliance? The direct answer is that it is the law. But perhaps that more important answer is that it is in our best interest to do so. Productivity depends on motivation. Workers are not likely to be motivated if their friends at the PTA think they work in a place that's messing up their town. Another reason it's in our best interest to comply with the law is because compliance is one way to help avoid future liability from environmental problems. We all know the potential liability from environmental transgressions is enormous. Even a "small" incident can lead to multi-million dollar cleanup and tort problems. This conclusion led many private companies to adoption of self-audit programs. We are also beginning to do audits on a large scale. A third reason that compliance is important is that it is essential to maintaining the credibility of the organizations. This is true in the public and private sector alike. I am convinced that an agency's environmental protection reputation significantly affects its ability to attract funds from legislators. My last reason why we should comply is more esoteric. Environmental protection is inseparable from the basic mission of the Defense Department. Protecting the nation includes protecting the quality of the places where we live and work.

Why Waste Stream Reduction?

Why are we focusing on waste stream reduction? This is almost entirely a goal of self-interest and good fiscal management. Waste causes problems with compliance, reporting, disposal storage, public relations, law suits and unknown future liabilities. The latter is by far the biggest risk and, as we know from the asbestos example, can run to the billions of dollars. These costs greatly outweigh the relatively small cost savings from inattention to waste stream management, the first step of which is waste stream reduction.

How To Achieve Our Goals?

How do we achieve our goals? Achieving our goals depends on a commitment by everyone involved. And by everyone I include defense personnel, our contractors, and our regulators. Through this commitment, we can work together to identify innovative, low-cost problem solutions. This total commitment greatly reduces the number of disputes which arise and which are often only excuses for not executing a program. Disputes involving minor issues of responsibility and funding perpetuate non-compliance. We need to do better in this area. The key is establishing a commitment at the local level to solve problems. Data show that we can solve a high percentage of our problems through local efforts.

Defense personnel, contractors, and regulators each have something special to offer as we work toward our goals. For

Defense personnel the first step is to clearly identify the problems we face. Secondly, we must assure that we are doing the best we can to cooperate with regulators. Doing otherwise always causes problems. Regulators will help if we are forthright. We have good examples of this, particularly in EPA Regions III, IV, and VI. Thirdly, Defense personnel must insist on excellence in the way people do work for us. Given the high costs of non-compliance, particularly in the hazardous waste area, anything less is unacceptable.

I have one particular plea to Defense personnel, and that is to provide me your ideas on how to improve our program. Send in those cards and letters. We really want them.

In the Office of the Secretary of Defense, one of the things we have done to help achieve our goals was to establish the Defense Environmental Leadership Project. Under this project we have gathered 6 environmental engineers to address the long-term problems of managing the Defense environmental program. We are working on hazardous waste policy development, risk assessment, industrial processes evaluation for waste stream reduction, and other long-range tasks.

<u>How can contractors contribute to achievement of our goals</u>?

How can contractors contribute to achievement of our goals? First, tell it like it is. Tell us what you believe, not what you think we want to hear. Help us by putting things in perspective. In my opinion, lack of perspective was a major shortfall in our early Installation Restoration program reports. For example, to say radioactive material is buried at a site, and not put in even the most gross bounds on how much waste is involved, is of little value in understanding the importance of the problem and can cause extremely adverse public response. Thirdly, contractors must do their best to offer innovative ideas. When you think you have good ideas and no one will listen, come to me. I will.

<u>What can regulators do to help achieve our goals</u>?

What can regulators do to help achieve our goals? Before looking at this, let me suggest that both Defense personnel and regulators must remember that if we are out of compliance, we both suffer. The public perceives non-compliance as a fault of the regulatory system. So it is in our collative interest to maintain a constructive relationship that will expedite compliance.

Now some points for regulators. First, I implore you not to keep secrets. If you think we are doing a bad job, tell us. Too often we find out what you are thinking through the press, the General Accounting Office, or the Congress. Regulators should note that Defense installation commanders have tremendous incentive to comply with the law. Military promotions swing on hairs. If a commander wants to be promoted, he won't let a pollution problem persist. Commanders know that good community relations are essential to esprit de corps on his installation. Bad publicity in environmental compliance is guaranteed to damage this important aspect of base operations.

What is the best tool a regulator has for stimulating compliance at Defense installations? I believe it is a simple letter to the commander identifying concern. Such letters can clearly indicate the importance of the issue to you, but need not create adversarial situation. It helps not to let things fester. Notify the installation commander promptly of your concerns. If you don't get a suitable response in a reasonable time, use problem resolution procedures involving a higher level of management in both the regulatory and regulated communities. Be sure to keep the communication channels open. Try to meet with Defense personnel when you don't have an issue to discuss. The rapport established under these conditions will expedite problem resolution later. Lastly, let me ask you not to skewer us on our own swords. If you discover a problem through auditing that we've done, you can be assured that we will work to achieve a solution. If in identifying a problem to you, we find ourselves the victim of adverse publicity or strong regulatory measures, our managers are unlikely to continue looking for environmental problems and your job will be tougher.

Gilding the Lily.

For all of us here, one of the biggest problems is to avoid "gilding the lily." It is very tempting to go for the super solution when resolving an environmental problem. This is destructive to the program because it reduces the resources available for cleaning up other sites, is an attack on the credibility of our work, and it may lead directly to a "golden fleece award."

Resources

Let me now briefly review the resources we have to address environmental problems. In the Defense Department we are expending nearly a billion dollars annually on the program, and we have 4,000 people engaged full time in the work. Our policy is to fund compliance projects immediately. We fund cleanup projects as soon as we know what needs to be done. However, we face the same problems as everyone else in determining how clean is clean and identifying the best way to attack cleanup problems.

As many of you know by now, we have a new account to fund hazardous waste cleanup problems in the Defense Department. In 1983, prior to establishing this fund, we expended $39 million in hazardous waste cleanup. Under the fund in 1984 we will expend $150 million, and we anticipate funding at a level of approximately $300 million a year until 1990. As we begin to approach the cleanup goal of 1993 program requirements should substantially decrease.

How Are We Doing?

Let me give you a little report card on how I think we are doing in the Defense Department in achieving our goals of compliance and waste stream reduction. In the area of air and water, I give us a fair. The bad news is we still have a lot of minor sources out of compliance, particularly in the water area. The good news is that our compliance for major sources is high and that we have projects underway that will eliminate all known non-compliance conditions for major sources. In the RCRA area, our performance is unclear. We are now conducting a survey which will give us a much better picture of how we are doing. We know that we don't have a large number of RCRA violations reported by regulators. However, we also know that this may be simply be because no one has looked carefully. In the TSCA area we have not done well but we are rapidly correcting the situation. About 15% of our installations failed to meet the January 1, 1984 deadline for eliminating PCB storage longer than one year. We now have a firm plan that will achieve compliance with this requirement by December 1, 1984.

In the hazardous waste cleanup area I give us the highest marks. Our cleanup program started in 1975, substantially before anyone else's. In 1980, even before the passage of the Superfund cleanup law, we greatly accelerated our program. Between 1980 and 1984 the program continued to increase steadily. The decision of the Congress to provide funding in 1984 at a much higher level than we had provided previously planned assured continuing increase in our effort. At the end of 1983 we had completed 257 of 429 installation assessments. We had 111 of 155 site studies completed or underway and we had over 28 cleanup actions in progress. We have completed our hazardous waste program actions at 122 installations.

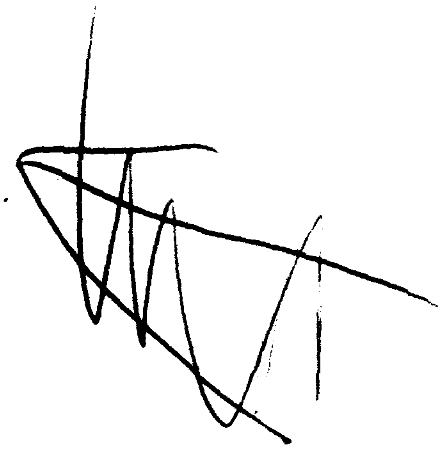
The Future

What does the future hold for our program? I see two things coming that will impact how we do business. First, EPA's decision to include federal sites on the National Priority List will undoubtedly affect our priorities. Ultimately we expect 200 installations to be scored for possible inclusion on the List and we expect 30 to 40 to ultimately be listed. Second, our initiative to do environmental audits will also affect our program. All three services are conducting work in this area. Although we do not have any DoD policy on environmental audits, we are thoroughly examining the benefits of establishing one.

Conclusion

We have done a lot to achieve our goals of environmental regulatory compliance and waste stream reduction. We've completed hundreds of projects and have numerous agreements with state and federal agencies in place. We have done over 300 record searches and have over 100 comprehensive contamination studies complete or underway. Our cleanup budget has increased over 700% in the last 3 years and we have had a 300% increase in the environmental staff in OSD. We added many joint EPA projects, and we greatly increased the amount of information we have made available to the public on our program. Defense personnel, our contractors and the regulatory community must work together to achieve our goals of complete regulatory compliance reduction [illegible] the amount of waste we generate.

Thank you and good morning.



Hazardous Wastes: Perspective on the Problem

Joel S. Hirschhorn

The national program for hazardous waste control depends principally on two Federal statutes. The Resource Conservation and Recovery Act (RCRA) of 1976, which has been amended and is in the process of being changed again by Congress, is concerned with the proper management of newly generated hazardous wastes and operating waste management facilities. The goal of this statute was to have an effective system to track hazardous wastes from the point of generation, through any transportation, to the ultimate treatment or disposal.

The Comprehensive Environmental, Response, Compensation, and Liability Act (CERCLA) of 1980, better known as Superfund, deals with a number of problems related to the uncontrolled release of hazardous *substances* into the environment, a subset of which is uncontrolled hazardous *waste* sites which may include abandoned dumps, inactive sites, or still operating facilities. Superfund came about, for the most part, because of widespread recognition of the many uncontrolled hazardous waste sites throughout the nation and the need to provide a mechanism to accelerate their control and cleanup. Congress will examine and consider extending and perhaps changing Superfund, whose major funding mechanism expires in 1985.

Most aspects of these statutes are implemented by the Environmental Protection Agency, although a number of other Federal agencies also have defined responsibilities. Moreover, the states — if they choose — have a major role in implementing these programs under the guidance and supervision of EPA.

The progress of the RCRA and Superfund programs has been surrounded by controversy, inspired in part by broader events within EPA. The hazardous waste programs have been criticized by virtually all interested and affected groups — from citizens, industry, and Congress to environmental groups and states — for moving too slowly, for being ineffective in protecting public health and the environment, and for being too complex, costly, and sporadic.

Mr. Hirschhorn is a senior associate at the Congressional Office of Technology Assessment where he directs studies on hazardous waste. The views expressed here are his own and not necessarily those of OTA.

While no one seems to be completely satisfied with the two components of the waste program, almost everyone will agree that the situation is far better today than it was before these programs were established. Credit for this must be given to the new regulatory programs and to the general public and industry leaders who are becoming more aware of the problems and the long-term liabilities and costs of improper management of hazardous wastes.

And yet many troubling issues remain, along with a reluctance to address these issues because of the prospect of still more changes in the government programs. Uncertainty about what wastes and facilities are to be regulated, and how, continues to trouble many people.

How Much of What?

What exactly do we mean by hazardous wastes? Even this has been a confusing and contentious issue, in part because of its complexity. Some wastes are considered hazardous because they have been listed by EPA, others because they exhibit certain characteristics. And then there are the gray areas; some states regulate more wastes as hazardous than the Federal program, and a careful reading of RCRA indicates that more wastes could and may be regulated as hazardous in the future.

One thing is clear: hazardous wastes are ubiquitous. Virtually all industrial and commercial operations, research establishments, educational or hospital laboratories, and military complexes, as well as many retail establishments, are likely to produce some type of hazardous waste. But data suggest that about one percent of hazardous waste generators account for about 90 percent of the wastes nationally.

Hazardous wastes range from synthetic organic chemicals to heavy or toxic metals, to inorganic sludges, to solvents, to dilute aqueous waste streams. They may be solid, liquid, or gaseous; they may be pure materials, complex mixtures, residues and effluents from operations, discarded products, or contaminated containers or soil. Most hazardous wastes are managed on the site where they are generated, more so in some states and industries than others, and more likely by larger plants and generators than by small ones.

The Office of Technology Assessment (OTA) estimates the total amount of hazardous waste generated annually as being from 255 to 275 million metric tonnes. Recent EPA data put the figure at 150 million metric tonnes, but it could rise. Federal and state data bases still are being developed.

Technologies

Virtually all waste management technologies can be broken down into three broad categories, starting with the most preferred: 1) waste reduction efforts, 2) treatment or destruction techniques, and 3) containment or land disposal.

Waste reduction. Spurred on by the rising costs and regulatory burdens of managing hazardous wastes,

EPA has given priority to establishing regulations for land disposal options. The result is a catch-22.

there is a trend to use more source reduction techniques. These include the relatively simple and low cost "housekeeping" approaches such as separation or segregation of various waste streams so that a smaller amount of hazardous waste remains to be managed. Then there are changes in raw materials and manufacturing processes which are more easily attained when designing new operations, and inplant recycling and recovery operations that are sensitive to market prices for their feasibility. A more difficult approach is end-product substitution. Reliable data on the extent of source reduction are scarce, but those working in the area of hazardous waste generally believe the process is becoming more economically attractive. Some states have imposed taxes on hazardous wastes, which also may help drive the system more in this direction.

Treatment and destruction. Studies by OTA and the National Academy of Sciences have concluded that a large number of waste treatment alternatives are waste specific. One or more treatment technologies already have been shown to be technically effective for every type of hazardous waste. Moreover, substantial research, development, and demonstration activities likely will lead to still more alternatives.

These technologies fall into several categories including: chemical treatments such as neutralization; thermal destruction in conventional incinerators or newer forms of high temperature devices such as fluid wall reactors and plasma arc furnaces; physical treatments such as precipitation, photolysis, and distillation; stabilization, fixation, and encapsulation treatments to form relatively insoluble and inert masses; and biological approaches based on naturally occurring or genetically engineered organisms to degrade certain toxic chemicals.

Many of these technologies are being used today on-site and in commercial waste management facilities. The extent of use, however, still is limited, more because of economic factors than because of lack of technical effectiveness. Generally speaking, the costs and market prices of treatment alternatives are substantially greater than those for most forms of land disposal, usually from $50 to several hundred dollars more per ton of hazardous waste.

OTA and others have suggested that the cost differential is caused by EPA policies and regulations that favor land disposal and ultimately lead to the "externalization" of some of the true short-term and long-term costs associated with it, i.e., the users are not paying all the costs because some are being shifted to the future. The reason for this is the high probability of failure of land disposal operations, and there are no firm assurances that current users of land disposal will bear the costs of future corrective actions, monitoring, or cleanups.

Moreover, EPA has given priority to establishing regulations for land disposal options. The result is a catch-22 situation. People are reluctant to use some treatment technologies that are unregulated, and EPA is prone not to promulgate regulations because the technologies are not being used. As an example of yet another dimension of this problem, EPA defines any residue or product of a treatment technology for hazardous waste as a hazardous waste. The burden of proof that it is not is with the treatment facility operator.

The Superfund program also has problems properly evaluating the cost-effectiveness of treatment options versus containment or land disposal. Nevertheless, most types of treatments can be modified for on-site use for remedial cleanups, or wastes and contaminated materials can be sent to treatment facilities. Also, special treatment approaches either are available or are being developed for uncontrolled site problems, notably for contaminated soils and aquifers.

Land disposal options. The prevalent method of managing newly generated hazardous wastes as well as wastes and contaminated materials from uncontrolled sites is land disposal; probably some 80 percent to at least 90 percent of all such materials are disposed of in this manner. One area of confusion, however, is the exact meaning of the term land disposal. Many people think of landfills when the term land disposal is used. In fact, more wastes go into injection wells and surface impoundments (pits, ponds, and lagoons) than into landfills. Then there are the categories of land spreading (also called land farming or land treatment) and ocean dumping. These are used for relatively small amounts of hazardous waste. Other forms of land disposal being examined and developed include the use of salt domes and deposits, underground mine cavities, and above ground vaults or bunkers which may be discrete fixed enclosures or above ground landfills.

In most of these cases the principal objective is containment of the hazardous wastes, i.e., separation of the wastes from the environment. But in others, such as ocean dumping and surface impoundments, the wastes are dispersed into the environment in a way designed to reduce adverse environmental impacts.

While some may disagree with the following generalizations, most objective studies of land disposal, whether they are theoretical, experimental, or based on actual field experience, reveal that land disposal cannot assure the long-term protection of public health and the environment. Land disposal containment systems fail; the major uncertainty is when. Some land disposal facilities have failed within only a few years. When one recognizes that many of the most toxic wastes will remain toxic for decades or centuries, it becomes more obvious that land disposal is not an acceptable long-term management option for these wastes. A fascinating paradox is that radioactive wastes, which in fact become less hazardous over time, now are regulated for hundreds and thousands of years, but land disposal facilities for hazardous wastes have to meet requirements for only 30 years.

Land disposal is popular because it is relatively inexpensive when compared with alternatives. Ultimately, however, someone will have to pay to clean up an uncontrolled site. The costs for that are at least 10 to 100 times greater than the costs to treat the waste in the first place.

Public opposition to land disposal facilities and to the siting of new ones has intensified, and not unjustifiably so, as technical information and experience support many concerns and fears. But it is unfortunate that the same public has difficulty in differentiating between land disposal and treatment facilities. The latter, if designed and operated properly, are similar to conventional manufacturing operations using hazardous materials as raw materials or producing them as products.

As the movement grows to shift from land disposal to treatment, legitimate concerns over the difficulties in siting waste treatment facilities will arise. To date, EPA has done little in the siting area, leaving it to the states to cope with the problem. Effective regulations for such treatment facilities also are needed.

Superfund Problems

The Superfund program has attracted most of the attention surrounding hazardous wastes. Because Superfund sites, by definition, consist of actual or imminent releases of hazardous substances into the environment, people exposed to the dangers of these sites have become vocal, well organized, and technically sophisticated, and have exerted considerable political pressure. More attention has been given recently to the "band-aid" character of remedial actions and the inadequacy (and some say immorality) of shifting wastes from one location to another. Several cleanup actions have failed soon after their completion while even more have dealt with only part of the problem, e.g., sites where open and leaking drums of waste and surface contamination are removed, but nothing is done to clean up a contaminated aquifer.

Part of the problem is the lack of specific national cleanup goals, generally referred to as the "how clean is clean?" issue. Central to the issue is the fact that cleanups may never lead to genuine, permanent solutions and can vary significantly from one site to another. Questions also must be answered concerning acceptable levels of residual contamination and commitments for future use of the sites.

Morever, major uncertainties remain as to the number of existing uncontrolled sites, their degree of hazard, and the likelihood of currently used waste facilities (even those for nonhazardous solid waste such as sanitary landfills) becoming Superfund sites. Combining the uncertainties about future cleanup technologies, cleanup goals, and the number of sites leads to considerable concern about what is needed for the Superfund program. OTA estimates that total cleanup cost could amount to between $10 billion and $40 billion, but since that estimate more sites have been revealed. In EPA's inventory there are some 17,000 uncontrolled sites and this will rise. (An unofficial estimate in the fall of 1983 increased the figure to 22,000.) Future costs could climb substantially, depending on EPA policies.

It is clear that controlling hazardous waste will remain a major national activity for many years to come.

The Future

What does the future hold? More wastes are likely to become regulated under RCRA. There will be more prohibitions for land disposal of certain types of wastes and regulations for land disposal likely will become more stringent. In addition, rising costs of waste management will motivate more waste generators to use source reduction. Eventually, some of the obstacles to greater use of treatment technologies will be removed, possibly with the government providing direct incentives.

Expanding the current five-year $1.6 billion Superfund program — perhaps using a tax on hazardous wastes generated instead of or in addition to the present feedstock tax — has attracted considerable interest. Some states have adopted this approach, both to raise funds and to tax land disposal higher than more preferred alternatives. EPA's implementation of Superfund, if the program is extended by Congress as expected, probably will undergo substantial changes over time. It is clear that controlling hazardous waste will remain a major national activity for many years to come. It also is clear that the waste management industry will expand, particularly as the focus shifts to developing and using more high-tech solutions. ▲▲

BAILEY GUARD
CHIEF CLERK
SENATE COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS

I am particulary glad to join your group this morning because in our work with environmental issues we see representatives of industry, state governments, and citizen groups; we see able professionals from the Environmental Protection Agency - but other than the Coast Guard, scarcely a uniform. Much less are we familiar with the environmental activities of the Department of Defense.

So this is welcome opportunity for me, if for no other reason than to illustrate the gulf between our institutions, and to call attention to the need for improved communication. I thank you also for this chance to meet with you, because it required me to think about this neglected area.

I hope it will neither surprise nor offend you when I say I believe the general impression among Members and staff on the Hill is that the environmental performance of Federal facilities, and of the agencies responsible for them, has been somewhat abysmal. I cannot document that impression, and I confess that there has been neglect on both sides. I do not propose to dwell on past failures, but they may be a measure of the nature of the challenge we face, and of the recent progress that has been made.

Following the excitement and the legislative activity which made the Senate Committee on Environment the focus of attention and accomplishment--with the Clean Air Act of 1970 and the Clean Water Act of 1972--and entire decade slipped by during which, it seems to me, Federal facilities environmental compliance demonstrated little more than sluggish bureaucracies reflecting the not-invented-here syndrome. Far from setting the example, rather than proudly showing what could be done with enlightened leadership, the general impression was of lethargy motivated by apathy. Partly, through ignorance, perhaps even from negligence, surely with a touch of arrogance-but mostly from a natural preoccupation with each agency's primary mission - environmental compliance became lost in the competition of each year's priorities.

If that characterization is overly harsh, I hasten to add that the institutional impediments were neither recognized nor dealt with. EPA priorities went to the States and communities and industries which cried out for attention. No great independent Federal agency can be expected to wax enthusiastic about some diversion which consumes both its budget and personnel. And the authorizing and appropriations committees already had a plateful, dealing with each great program of government.

After a long dry spell, it appears that, with your help, this situation is now being turned around.

I hear instead of the change in attitude, and new leadership since the arrival of Peter Daley. Ruckelshaus' policy, through Al Alm and our friend Josephine Cooper, once more looks to setting the Federal example. And not only for the example of a job well done, but also for the very practical consequence of a gain against pollution--which becomes as positive a contribution to the whole effort whether it be a utility stack, a municipal treatment plant, a private car, or an Army dump. Just as practical, is avoiding the black mark which folks find it so easy to chalk up, if I may mix a metaphor, against Uncle Sam.

The 1968 and following executive orders appear finally to be bearing fruit--in the EPA yellow book and the policies it incorporates. Both, I recognize, will be sterile and unproductive unless accompanied not only be cooperation, but also be genuine initiative, good will, and hard work by every contributing agency.

Most of all, the great alibi for inaction over the years has been no appropriations--when we understand very well that agencies know how to get money for those things vital to them. So again, it is a pleasure to have Jo Cooper remind me of the $50 million line item to get to work on DOD dumps.

I really did not mean to preach a sermon, or to sing you a hymn of praise. My subject is supposed to be changing environmental attitudes. So I will comment, in a general way if I may, on those I see close at hand among the Members and staff of the Senate Committee on Environment and Public Works.

First, as to media, as it is called, we began seriously in 1970 with air, and two years later on clean water. Then in 1976 we tackled an even more intractable subject, solid waste, at the same time we were trying either to fine tune or to further complicate the air and water programs. Now, following superfund and Love Canal and Times Beach, attention is more and more on toxics, hazardous emissions, carcinogens, mutagens-- in short, poisons.

While it is not a field that particularly entrances me, I think that trend is likely to continue. It is obviously a subject with an almost endless capacity to attract public interest, and one which grips the attention of a generation fascinated by diets, and enthralled by nature. And, I submit, it is past the time that we should move from NOX and smog, and from SO_2 and acid rain, to the hazardous air pollutant and the hidden mysteries of the water we drink.

A broad new area of interest is groundwater--to which one of devoted new Members, Senator Durenberger of Minnesota, has already given a great deal of attention. Here is a subject that promises to cross even more jurisdictional lines, and require cooperation between even more disciplines and institution. On our own Committee, Senators Abdnor and Moynihan have the rivers and harbors that feed the groundwater. Senators Durenberger and Baucus are responsible for the safe drinking water drawn from the groundwater. And Senators Chafee and Mitchell have the dumps and sites that polluts the groundwater.

An example of how rapidly attention is being focused is the new issue of leakage from underground tanks. Our subcommittee hearing of November 29 surfaced the issue, followed by additional hearings, staff work, introduction of a bill, and now every prospect that the Durenberger underground tank amendment will be added to the extension of RCRA when it is taken up in the Senate next month.

The time for huge new grants programs is gone. New initiatives involving trust funds, or fixing liability maybe. That leaves regulatory and enforcement measures, and all of us are shy of over-regulation. So it may be that the very best we can do is just to carry out, and work to complete, and improve upon, and make more efficient and more equitable the environmental programs and projects already put on the track.

A real swing in attitude seemed most likely three years ago, about the time the Republicans gained control of the Senate for the first time since I have been watching it. The Clean Air Act was at the top of the list of regulatory reforms. The Chamber of Commerce spread the word that the Clean Air Act, Clean Water Act and all were about to expire which would provide the opportunity for revisions and for changes which, in retrospect, could have cut as wide and as deep as those industry secured in tax changes. But that time has clearly passed.

Let me describe briefly the work of the Committee.

After two years work following nearly 30 days of hearings and as many markups, our Committee in 1982 reported clean air extension and modifications by a vote of 15 to 1. One week ago today, after two days in markup, with an enlarged committee--in fact four new members--the Committee reported 138 pages of clean air amendments by a vote of 16 to 2. This time the acid rain title requires a 10 million ton amendment reduction in SO_2, rather than 8 million tons. Attitudes appear to be solidifying rather than changing.

Clean air and clean water no longer rivet the nation's attention as they did when the Senate Public Works Committee was redesignated the Committee on Environment and Public Works. The most pressing national priorities remain the deficit, with its threat of inflation, and of program pruning; the Middle East; nuclear war. But it seems to me that the environment, like civil rights which proceded it, has moved from discovery and protest to orthodoxy and dogma.

A remarkable consistency has invested the work of the Senate Committee, reflecting, I must believe, a national concensus, and what has become a more or less settled public view. Before leaving the office, I looked back at the membership of the Committee at the time of enacting the Clean Air and Clean Water Acts, and found of present Members only Howard Baker and Robert Stafford on our side, and Jennings Randolph and Lloyd Bentsen on the other. Stafford, now Chairman; Baker, now Leader but leaving; Bentsen on deck. By 1976, when the Committee was so deeply involved in RCRA as well as air and water, Quentin Burdick and Gary Hart had become members. Alumni such as Bob Dole, Jim McClure and Pete Domenici have quite an enhanced policy role in the Senate of today. As I mentioned, Senators Evans and Lautenberg are quite new to the Committee, as were Dave Durenberger and Gordon Humphrey last year.

Yet, with these changes in membership, with the changes in national mood, with rather profound changes in technology and the cultural life of our country, and across several changes in administrations, the direction of policy for environmental protection and the general approach of Congress-- so far as one can characterize such an amorphous institution-- remains consistent.

I do not know whether this is helpful to you. But I hope it may provide some guidance that is useful--just as it may be the most useful thing for industry and municipalities to have at least some assurance that they can plan, and work, and invest, with the expectation that that investment of time and effort will produce a worthwhile result, will not be cast aside in favor of some new whim, but will accomplish some lasting result for good.

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THE APPLICATION OF EMISSIONS TRADING TO DOD INSTALLATIONS

By

Richard D. Cunningham
Dewberry & Davis
8401 Arlington Boulevard
Fairfax, Virginia 22031
(703) 849-0100

and

Gordon L. Brady, Ph.D.
Council on Environmental Quality
722 Jackson Place, N.W.
Washington, D.C. 20006
(202) 395-5780

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1.0 INTRODUCTION

One of the first major environmental regulatory reform efforts under the Reagan Administration is the Emissions Trading Program. The program provides that States may develop, for Federal approval, a system that allows facilities to trade permits to discharge air pollutants. Participation on the part of the States, Federal Facilities, and activities is purely voluntary.

The Emissions Trading Program allows relaxation of discharge limitations on one location within an activity while requiring a greater degree of abatement at other locations within the facility or within the region. Shifting the regulatory focus from point source control to the activity level has important administrative and efficiency implications. The activity that produces pollution may consist of a set of one or more unit processes and unit operations. Examples are an industrial plant, a shipyard, a jet engine testing facility, an office building, a boiler plant, a fuel storage area, or a motor vehicle. Each generates by-products according to some time pattern; it is at the activity level rather than at the individual point source that reductions in discharges can be most efficiently brought about.

This paper addresses the potential use of Emissions Trading at DoD installations. Section 2.0 provides a discussion of the Clean Air Act. Section 3.0 summarizes the Emissions Trading concept. Section 4.0 provides three case studies of Emissions Trading, viz., Lemoore Naval Air Station, Norfolk Naval Shipyard, and the Tri-Services Emissions Trading Project. We conclude in Section 5.0 that efforts to incorporate Emissions Trading in the DoD installation planning process will be important as the future development of this air quality management system takes place.

2.0 CLEAN AIR ACT

The U.S. Clean Air Act (CAA), as amended, contains four major provisions for managing air quality as it is affected by stationary sources. These comprise the following:

- The U.S. Environmental Protection Agency (EPA) established National Ambient Air Quality Standards (NAAQS) for so-called "criteria pollutants," viz., primary standards to protect human health and secondary standards to protect welfare (see Table 1)

- EPA was required to establish emissions standards for sources of pollution that were constructed after the issuance of regulations (called New Source Performance Standards (NSPS))

- States were required to prepare implementation plans (State Implementation Plans or SIPs) showing how they would achieve and maintain the NAAQS

- EPA was required to establish National Emission Standards for Hazardous Pollutants (NESHAPS)

The principal elements of air quality management in the CAA includes direct regulation through conditions placed on the operation of activities that

TABLE 1. NATIONAL AMBIENT AIR QUALITY STANDARDS

Pollutant	Averaging time	Primary standard levels	Secondary standard levels
Particulate matter	Annual (geometric mean)	75 µg/m³	60 µg/m³
	24 hrs [c]	260 µg/m³	150 µg/m³
Sulfur oxides	Annual (arithmetic mean)	80 µg/m³ (0.03 ppm)	—
	24 hrs [c]	365 µg/m³ (0.14 ppm)	—
	3 hrs [c]	—	1300 µg/m³ (0.5 ppm)
Carbon monoxide	8 hrs [c]	10 mg/m³ (9 ppm)	10 mg/m³ (9 ppm)
	1 hr [c]	40 mg/m³ [a] (35 ppm)	40 mg/m³ [a] (35 ppm)
Nitrogen dioxide	Annual (arithmetic mean)	100 µg/m³ (0.05 ppm)	100 µg/m³ (0.05 ppm)
Ozone	1 hr [c]	240 µg/m³ (0.12 ppm)	240 µg/m³ (0.12 ppm)
Hydrocarbons (nonmethane) [b]	3 hrs (6 to 9 a.m.)	160 µg/m³ (0.24 ppm)	160 µg/m³ (0.24 ppm)
Lead	3 mos	1.5 µg/m³	1.5 µg/m³

[a] EPA has proposed a reduction of the standard to 25 ppm (29 mg/m³)
[b] A nonhealth-related standard used as a guide for ozone control.
[c] Not to be exceeded more than once a year.

Source: Council on Environmental Quality. Environmental Quality 1981. Washington, D.C.: U.S. Government Printing Office, p. 25.

discharge pollutants. Permits to operate often include the specification of discharge limits from stationary sources, the specification of production processes (technology), and the specification of the quality of input materials to production.

The second element includes a monitoring and enforcement program to ensure that the sources comply with the conditions specified in the permit; various types of economic incentives, such as tax credits, low interest rate loans, rapid depreciation for investment in "air pollution control" facilities, and penalties for noncompliance. Conceptually, the regulatory structure of the CAA is driven by the objective of achieving the NAAQS.

The CAA is based upon a "command and control" regulatory approach. It prescribes discharge requirements on a point source basis. The administrative, monitoring and surveillance costs of this approach are relatively high. For example, a petroleum refinery may contain a combination of point sources including 8,000 valves, 24,000 flanges, 450 pumps, 50 process drains and three flares, each with its own abatement requirements. The prescription of control requirements to this level disregards the skill and enterprise incentives of a facility manager and other decision-makers in fashioning approaches that meet air quality requirements in the most cost-effective manner.

Other shortcomings have been observed in implementing the CAA. First, the air quality management information base is both limited and often inconsistent. Second, the monitoring and inspection of facilities has been insufficient. Third, agencies have tended to provide meager guidance in selecting the most appropriate pollution control equipment. Fourth, the present regulatory framework does not serve to facilitate the development and use of innovative control technologies. Lastly, the use of legal sanctions to bring violators into compliance has not been effective.

It is not entirely surprising, therefore, that the effectiveness of the current regulatory approach to air pollution control has been criticized. Critics have claimed that not only do costs exceed benefits, but capital has been diverted from more productive investments, productivity has been reduced, and innovation has been stifled.

3.0 EMISSIONS TRADING

The EPA Emissions Trading Program represents a practical approach to solving the air quality problems in terms of economic benefit.* Emissions Trading sets an absolute limitation on the quantity of specific pollutants present in the atmosphere for a region. The amount of pollution allowable by individual facilities in the region is fixed by permits-to-operate. Once these discharge limitations are set, the Emissions Trading Program allows existing facilities to trade among themselves--based on which dischargers can achieve the most

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*U.S. Environmental Protection Agency. "Emissions Trading Policy Statement: General Principals for Creation, Banking, and Use of Emission Reduction Credits." Federal Register, Vol. 48, No. 170, August 31, 1983, pp. 39580-39586.

cost-effective reduction in their discharges. This means that some facilities may control more than others while the region as a whole meets its ambient air quality goal.

A trading system in discharge permits represents the natural evolution of such innovative administrative procedures as the bubble, offsets, and banking--developed by EPA in response to increased understanding of air quality management and the limitations of current regulatory approaches.

The bubble policy allows variation, instead of requiring uniformity in pollution controls among points of discharge within a single industrial process provided that overall regional air quality goals are maintained.

The offset policy allows the owner of a new plant to operate provided that it obtains equivalent reductions in the discharges of pollutants from owner(s) of existing plants.

Banking, the most recent EPA program, allows suppliers of discharge reductions to receive "credit" for those reductions. The "credits" may be used (or sold) later and can allow the user to exceed otherwise prohibited applicable standards. The Emissions Trading Program consolidates the bubble and offset procedures in a single transactional instrument called an Emission Reduction Credit (ERC). The creation of the ERC is limited to reductions by existing dischargers below minimum requirements. Traders are required to demonstrate equivalent ambient effects from transactions in ERCs.

The U.S. EPA has estimated that the savings from approved and proposed bubbles can be over $200 million (see Table 2 for a listing of bubble applications by industrial category). The EPA has further estimated that the total savings from all bubbles approved, proposed, or under development to date can be over $700 million. For example, by changing fuels, the Narragansett Electric Company of Rhode Island achieved an annual savings of $3 million while reducing discharges of sulfur dioxide by 39 percent below requirements. A change in control has been reported to save Armco Steel in Middletown, Ohio, $10-14 million in capital costs for equipment to control particulates and $2.5 million in annual operating costs. Table 3 provides a listing of cost savings of several approved bubbles.

4.0 CASE STUDIES

In seeking to explore the application of Emissions Trading to DoD installations, three case studies are offered. Two deal with attempts to utilize Emissions Trading at DoD installations; the first involves attempts to control Nitrogen Oxide emissions from jet test cells at Lemoore NAS in California, and the second deals with the use of Emissions Trading to control particulates from boiler operations at the Norfolk Naval Shipyard in Virginia. The third case study does not address a specific DoD installation, but a Tri-Service effort directed toward developing emissions trading guidance.*

*Other case studies could conceivably have been addressed, e.g., excess controls at McClellan AFB in California. We believe, however, that the case studies selected best illustrate valuable lessons to be learned from applying Emissions Trading to DoD installations.

TABLE 2. BUBBLE APPLICATIONS BY INDUSTRIAL CATEGORY

Type of Industry	Change in Control			Process Change	Fuel Switch		Total
	TSP	VOC	SO_2	VOC	TSP	SO_2	
Iron Steel	7						7
Other Metals, including Cement							
Chemical Mfg						1	1
Utilities			1			3	4
Greenhouse						2	2
Coating - paper, tape, wire		2		2			4
Coating - cans, appliances, autos				1			1
Distillery	1						1
Pulp and Paper	1					1	2
Tires and Plastic				1			1
Glass	2				1		3
Other	—	—	—	—	—	1	1
Total	11	2	1	4	1	8	27

VOC = Volatile Organic Compounds, hydrocarbons that react with NO_2 to form photochemical oxidant, also called ozone (O_3). TSP = Total Suspended Particulates. SO_2 = Sulfur Dioxide.

Source: U.S. Environmental Protection Agency. EPA lists 33 approved bubble transactions as of September 20, 1983. Several did not fit within the categories above, e.g., Fasson-Avery International, Lake County, Ohio, involved a solvent input change and change in control technology; General Electric and Borden Chemicals in Louisville, Kentucky, involved ERCs purchased or leased from other dischargers; General Portland, Tampa, Florida, and U.S. Steel, Allegheny County, Pennsylvania, involved ERCs created from shutdowns. EPA has not provided a final ruling on the acceptability of ERCs created from production curtailments or plant shutdowns.

TABLE 3. REPRESENTATIVE CONTROL COST SAVINGS FROM APPROVED BUBBLE TRANSACTIONS

Firm	Industrial Category	Type of ERC	Cost Savings
3M Bristol, PA	Tape and packaging	Process change VOC	\$3 million capital, \$1.2 million annual operating costs
Kentucky Utilities Muhlenberg, KY	Electric Utility	Change in control SO_2	\$1.3 million annual operating costs
General Motors Defiance County, OH	Foundry	Change in control TSP	\$12 million capital
National Steel Corp., Weirton, WV	Integrated steel	Change in control TSP	\$30 million capital
U.S. Steel Fairless Hills, PA	Integrated steel	Change in control TSP	\$27 million capital
J.H. Thompson Kennett Square, PA	Greenhouse	Fuel switch SO_2	\$100,000/yr operating
Scott Paper Co. Chester, PA	Paper mill	Fuel switch SO_2	\$220,000/yr operating

Source: U.S. Environmental Protection Agency. "Status Report on Emissions Trading Activity," Memorandum, November 8, 1983.

4.1 Lemoore Naval Air Station

The Lemoore Naval Air Station (NAS) is located in central California near Hanford, California. The local air quality agency is the Kings County Air Pollution Control District. Implementation of the emissions trading concept focused on emissions from Test Cell #3 for the performance verification of the F404 aircraft engine at the NAS.

The central issues associated with this case emerged in the course of an initial review by the District, viz., possible exceedence of the District's 200 pounds per day New Source Review offset threshold for Nitrogen Oxides.

On April 2, 1982, the District issued a Conditional Permit requiring the NAS to identify offsets.* Approval conditions included offsets at a ratio of 1.2:1 if Lemoore tested one or more F404 aircraft engine per day. Upon receipt of additional data, the District would determine whether emissions are less than the threshold offset.

In March 1983, Lemoore provided test run data to the District. The estimated NOX emissions were 209.8 pounds per day; this exceeded the offset threshold. This estimate was calculated by the Naval Air Propulsion Center in Trenton, New Jersey (see Tables 4 and 5). The letter also specified a number of areas which must be addressed, i.e., emissions factors for tracking NOX emissions, and the determination of acceptable offset sources should conditions arise which necessitated them (contingency offset requirements).

In an April 5, 1983, letter to Lemoore from the District, the District accepted an emissions estimate of 130.3 pounds per day of NOX per F404 engine. The District, however, rejected Lemoore's request for an extension citing Rule 205 (which gives a two-year extension but allows not further extensions). The Authority to Construct was conditioned upon the following requirements:

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*In February 1979, the Ninth Circuit Court of California held that the Federal Clean Air Act could regulate the noise, visible emissions (smoke) and Nitrogen Dioxide emissions from Naval jet facilities. Of the jet facilities at 55 installations, there were 295 unabated facilities, 75 jet cells, six sound suppressors, and four hush houses. In designing compliance, a number of options were included, viz., specific design of the engine, level of engine maintenance, integrity of performance, high temperatures or exhaust, and high velocities of exhaust. A number of additional considerations, however, affect specific compliance decisions, e.g., unabated facilities/sound suppressors create pollution intensities at ground level, jet cells are deteriorated thereby requiring extensive maintenance, and new/major modified jet facilities require NOX wet-chemical scrubbers unless offset sources can improve local air quality of nonattainment regions. At that time, it was recognized that additional research and development was needed. A pilot study on air quality improvement for NOX offset requirements was recommended at Alameda NARF or Lemoore NAS.

TABLE 4. BASIC EMISSIONS ESTIMATED BASED ON NAVAL AIR PROPULSION CENTER FUEL FLOW AND EMISSION FACTORS

Power Mode	Time in Mode (Min)	Fuel Use Lbs/Hr (Gal/Hr)	Fuel Use During Time in Mode	Emission Factor Lbs/1000 lbs Fuel	NOX Emissions (Lbs)
GI	25	623.9 (91.48)	38.12	1.16	0.30
FI	20	814.8 (119.47)	39.82	3.00(1)	0.81
IRP	25	8586.9 (1259.08)	524.62	25.16	90.02
A/B	10	28396.5 (4163.71)	693.95	9.22	43.64
			Σ = 1296.51		Σ = 134.77

[1]AESCO estimated this factor from a plot of fuel use versus reported emissions factors by NAPC.

TABLE 5. ADDITIONAL INCREMENT ADDED TO TABLE 5 EMISSIONS TO ACCOUNT FOR 1800 GAL/ENGINE RUN

Power Mode	Time in Mode (Min)	Fuel Use Lbs/Hr (Gal/Hr)	Fuel Use During Time in Mode	Emission Factor Lbs/1000 lbs Fuel	NOX Emissions (Lbs)
GE	20.55	623.9 (9.48)	31.33	1.16	0.25
FI	20.55	814.8 (119.47)	40.92	3.00	0.84
IRP	20.55	8586.9 (1259.08)	431.23	25.16	74.09
			Σ = 503.48		Σ = 75.09
			ΣΣ = 1799.99		ΣΣ = 209.86

Source: U.S. Navy. Letter with Attachments to Kings County Air Pollution Control District. San Bruno, California: Naval Facilities Engineering Command, Western Division, 1 March 1983, p. 2.

- Source testing for determining compliance

- Testing of one or more F404 engines may require offsets at a ratio of 1.2:1 per pounds of NOX emitted

The District requested that Lemoore provide a list of potential offsets following the initial operation of the test cell.

In a June 24, 1983, letter from the District, it was recognized that the critical issue was pounds of NOX emitted per day and not necessarily the number of engines tested. The District, therefore, accepted Lemoore's recognized position that actual emissions could be calculated with reasonable accuracy based upon the cumulative time spent in each power mode using emissions factors. Also accepted was that Lemoore would limit emissions of NOX from the test cells to 200 pounds per day. The District rejected, however, Lemoore's contention that purely manual recording of time spent in each testing mode would be an acceptable way to monitor emissions.

Subsequently, Lemoore indicated that the monitoring of NOX from test cells could be accomplished by a manually administered system rather than a continuous system with charting capability. Lemoore also indicated that a predictive rather than an actual recording system was needed to monitor the emissions. Specific guidance from the District was requested concerning the adequacy of addressing the offset requirements.

As can be seen from the above, extensive consultation was carried out between the Navy and civilian air pollution control officials. As of this writing, a resolution has not been reached. Lemoore has submitted emission factor data, offered an alternative monitoring approach, and requested guidance as to whether conditions permitted approaches other than those which would require the use of offsets.

4.2 Norfolk Naval Shipyard

The Norfolk Naval Shipyard is located in Portsmouth, Virginia, within the Hampton Roads Intrastate Air Quality Control Region. The principal activities pursued at the Shipyard include overall construction, repair, alterations, drydocking and outfitting of ships and other water crafts. Pollutants are generated by painting, sand and grit blasting, plating, degreasing, metal forging, and boiler operations.

Activities at the Norfolk Naval Shipyard are aggregated into several land areas that are separated by various natural and manmade features. The areas include housing tracts (New Gosport and Stanley Court areas), areas where ships are laidup for extended periods of time (South and St. Helena's Annex), extended shipyard services (St. Julien's Creek Annex), and the main Naval Shipyard.

The principal issue associated with this case study involved emissions from boilers. There are 56 boilers located throughout the Shipyard. The types of fuel burned include natural gas, distillate and residual oil, and refuse. The boilers provide steam for process equipment, equipment testing, generating electricity and space heating.

Eight of these boilers are the subject of this case study. They exceeded the Commonwealth of Virginia's particulate emissions limits. In particular, the Main Steam and Power Plant, Building 174, exceeded air standards by approximately 60 percent, and the Salvage Fuel Fired Boiler Plant, Building 1460, exceeded emissions limits by up to 90 percent.

The Main Steam and Power Plant consists of six boilers and was constructed between 1939 and 1944. Particulate emissions were controlled by large diameter cyclones. The Salvage Fired Fuel Boiler Plant consists of two water wall boilers completed in 1977 and burned refuse, as received, on reciprocating grates. Particulate emissions were controlled by a single field electrostatic precipitator.

During 1979, studies were performed in order to devise corrective actions. It was found that because the efficiency of the Main Steam Plant's boilers had deteriorated to an estimated 70 percent; unburned carbon made up approximately 60 percent of the particulates being emitted from the stack. Due to the age of the plant and preliminary stack emission results, final compliance with Virginia Air Pollution standards could not be guaranteed. The Salvage Fuel Boiler's electrostatic precipitator was found to be deficient in removal efficiencies due to several factors, e.g., power levels, size of the unit, spark rate control and transformer/rectifier controls. In order to achieve emission levels specified in its permit, it was recommended that a new electrostatic precipitator be installed upstream of the existing one.

The cost of these corrective items was estimated to be approximately $6 million for the Main Steam Plant and $2.6 million for the Salvage Fuel Fired Boiler Plant (see Table 6). For the Main Steam Plant, approximately $2.6 million was for the repair and improvement of boiler efficiency. Because the Virginia Air Pollution Control Board wished that this facility be brought into compliance as rapidly as possible, it was determined that $3.7 million be included for an electrostatic precipitator.

While these factors were being considered, several events took place which created a favorable situation for the application of a "bubble." First, plans associated with a regional Trash Burning Plant had been finalized; Shipyard officials became skeptical about spending $8.9 million for bringing facilities into compliance when these facilities would be replaced within a few years. Second, the Virginia Air Pollution Control Board determined that salvage fuel fired boilers were not incinerators; the standard that would have to be met, therefore, was the Virginia regulation for existing boilers. Finally, the Virginia Air Pollution Control Board promulgated their Bubble Policy in January 1980 and suggested an allocation of allowed particulates emissions.

With this in mind, four bubbles were formed around the Shipyard. One was over the main Shipyard for the stationary-permanent boilers; another was formed for the stationary-portable boilers; a third bubble was formed for the South Annex boilers; and finally a bubble was developed for the remote housing site boilers. This approach allowed the Main Steam Plant to come into compliance while not being required to install an electrostatic precipitator; the savings due to this bubble was estimated to be approximately $3.7 million. The

TABLE 6. ESTIMATED COSTS FOR CORRECTIVE ITEMS FOR THE MAIN STEAM PLANT AND SALVAGE FUEL FIRED BOILER PLANT

Item	Cost(1)
Main Steam and Power Plant	
Repair Combustion Controls	154,000
Replace Dust Collectors	441,000
Repair Breeching	673,000
Rehabilitate Boiler No. 10	421,000
Replace Oxygen Meters	15,000
Rehabilitate Boiler No. 11	722,000
Repair Smoke Stack	206,000
Additional Pollution Control Device	3,700,000
	6,332,000
Salvage Fuel Fired Boiler Plant	
Repairs to Electrostatic Precipitator	110,000
Construct New Multi-Cyclones	300,000
Install Opacity Meters	15,000
Additional Electrostatic Precipitators	2,200,000
	2,625,000

[1]Estimated costs expressed in 1982 dollars.

Source: Thompson, Charles. Application of the Bubble Concept to Fuel Burning Sources at a Naval Industrial Complex. Houston, Texas: Fourth Symposium on the Transfer and Utilization of Particulate Control Technology, October 1982, pp. unnumbered.

Salvage Fuel Fired Boiler compliance involved upgrading the existing electrostatic precipitator and installing a precleaning multi-cyclone; this represented a savings estimated at $2.2 million. The total savings estimated to be realized from the application of the bubble concept was approximately $5.9 million in capital costs and approximately $55,000 in annual operating costs.

Subsequently, performance testing of the Main Steam and Power Plant and the Salvage Fuel Fired Boiler indicated new problems; it was concluded that the bubble would not be required for the Main Steam Plant in order to achieve compliance. Furthermore, performance of the new multi-cyclones and upgraded precipitators at the Salvage Fuel Fired Boiler was far less satisfactory than anticipated. As a consequence, a new bubble will have to be developed.

Even though difficulties were encountered in terms of equipment performance, a potential cost savings was demonstrated through the use of the bubble concept rather than the usual "command and control" air quality approach. This was not done, however, without the generation of appropriate emissions data, the carrying out of performance testing, and balancing of numerous decisions associated with capital equipment acquisition and rehabilitation. Finally, the development of an appropriate regulatory mechanism greatly facilitated the application of the bubble concept at this installation.

4.3 Tri-Service Emissions Trading Project

This case study is quite different from the above two in that it does not involve a specific facility to which emissions trading was applied or is being tried. Instead, it involves all three Services of the U.S. Department of Defense in seeking to develop emissions trading guidance and the formation of an organizational users group.

The effort was first funded in 1979 by the U.S. Navy, Naval Facilities Engineering Command (NAVFAC). Work was centered at the Naval Surface Weapons Center in Dahlgren, Virginia. Subsequently, the U.S. Army and U.S. Air Force joined with NAVFAC in supporting the development of this tri-Service emissions trading project.

Impetus associated with the initiation of this effort involved several factors. First, many military facilities cannot be readily relocated to other sites which might afford more favorable circumstances for the control of pollutants. The location of many military facilities is dictated by national defense considerations. With this in mind, there was the need to incorporate all potential factors in the planning of military installations for outreach years; this involved planning for environmental permits and the choice of equipment. Finally, it was concluded that emissions trading offered a potential source of cost savings compared to the prevailing command-control air pollution approach.

Presently, DoD is assisting in the development of an emissions trading guidance manual. The manual will provide instruction and guidance to this alternative air pollution control approach, and is intended for use principally by facility engineers.

At the present time, the proposed emissions trading manual will address the following major factors:

- Reasons for utilizing emissions trading
- Processes allowed for emissions trading including preconstruction review and permitting, and creating Emission Reductions Credits for future use and planning
- Actual and hypothetical examples of DoD emissions trades (10-12 examples covering netting, offsetting, bubbles, and banking)
- Procedures for calculating emission increases, emission reductions, and Emission Reduction Credits (ERCs)
- Technical issues and information concerning key agency contacts, preconstruction review, modeling, fugitive dust, visibility, and banking procedures
- Summarization of state and local regulations
- Documentation and use of emissions trades

Hypothetical examples will be formulated in terms of actual potential use, viz., they will be developed with real issues in mind while not being applicable to any specific facility. These examples will address the nature of an operation at a facility and the pollutants generated, the calculation of emissions and options for control, existing uncontrolled sources of this pollutant(s) at the facility, the identification of strategies and the calculation of costs for each strategy, and factors associated with the selection of one control strategy over another.

The manual will emphasize achieving compliance at the minimum cost, and the comparison of central options in terms of cost and benefits. Appendices will cover the history of emissions trading, applicable policy statements, information sources, and other reference materials.

The emissions trading manual is scheduled for completion in the summer of 1984. Following the completion of the manual but prior to distribution, a field evaluation will be performed at various DoD installations. Thereafter, a revised emissions trading manual will be issued as guidance to the three Services. When the emissions trading manual is completed, it is planned that a Tri-Service Users Group will be formed to coordinate and facilitate trades among facilities associated with the respective DoD Services.

This effort represents an important step in developing emissions trading applications throughout DoD. On the one hand, it represents an effort to raise awareness about alternative approaches to air quality management that hold the promise of real cost savings. On the other hand, it also provides guidance on the way to carry out an emissions trade.

Beyond these immediate program development and implementation steps, the Tri-Services Emissions Trading Program represents an important effort in areas where the CAA has been only marginally successful. Specifically, this involves the incorporation of pollution controls into the decision-making process and the encouragement of technological innovation. In the civilian sector, business decision-makers have frequently been reluctant to try new technologies for controlling pollutants, particularly since it may be relatively unknown if these technologies would impede the manufacturing or production process.

DoD Services perform planning for outreach years, viz., up to seven years in the future. As such, it can be determined well in advance when environmental permits will be required. Emissions trading readily fits into this advanced planning process by identifying tangible cost savings among equipment choice. With this advanced knowledge of control equipment needs, innovative technologies can be developed in order to meet air pollution control requirements. It can be seen, therefore, emissions trading not only fits in well with DoD planning and the meeting of CAA requirements, but also might lead to the development of innovative control technologies. In this regard, the Tri-Services Emissions Trading Project may provide valuable lessons to civilian Federal agencies and the private sector.

5.0 CONCLUSIONS

Based upon our analysis of the above installation-specific case studies, we conclude that limited application has been achieved by DoD installations in using Emissions Trading as an alternative to the "command-control" approach. While the Norfolk Shipyard case study demonstrated that hypothetical cost savings were possible, these have yet to be realized because of the occurrence of equipment performance failures. In the case of Lemoore NAS, no definite conclusion can be offered with regard to the operation of the Emissions Trade by virtue of the fact that the decision-making process has yet to run its full course.

With regard to both Lemoore NAS and the Norfolk Naval Shipyard, it is quite clear that prolonged and extensive negotiations were encountered in seeking to complete an Emissions Trade. This required the gathering and analysis of data, the exploration of feasible trade candidates, and the process of negotiation.

Both Lemoore and Norfolk demonstrate, however, that Emissions Trading is facilitated, in the first instance, by the existence of a rule or policy that allows greater flexibility in meeting permit requirements than has been the case under the "command-control" approach. Beyond this initial impetus, we have seen that participants in the decision-making process must be knowledgeable in the possibilities for pollutant control offered by Emissions Trading and must, in addition, have all the necessary emissions and control data available in order to realize these possibilities.

These factors confirm the importance of the current Tri-Service Emissions Trading Project. Through the review of the guidance manual that is presently being developed, personnel at DoD installations can become more familiar with the technical issues associated with successfully completing an Emissions Trade. The guidance manual will also raise the awareness of personnel concerning feasible alternatives to the current "command-control" air pollution approach such that real cost savings can be realized. In completing this guidance manual, however, it is necessary that substantial attention be paid to the differences among the Services both with regard to their activities and the nature of their respective organizations; if this is not done, then the manual will only be of general interest.

The Tri-Services Emissions Trading Project also offers a unique opportunity in an important area where achievement has eluded civilian agencies up to this time, viz., fostering the use of innovative technologies for the control of air pollutants. By incorporating Emissions Trading into the planning process for outreach years, pollution control issues can be identified well in advance of the filing of a permit; this can allow for the consideration of new control techniques that are potentially more effective and efficient. If this potential is fulfilled, then the use of Emission Trading within the planning process will be a benefit to DoD and provide a constructive example to civilian agencies and the private sector.

On the whole, we conclude that efforts to incorporate Emissions Trading into the DoD planning process will be important as the future development of this system takes place. As the Lemoore and Norfolk case studies illustrate, however, actual successes at the installation level thus far have been limited for various reasons. With this in mind, we suggest that Emissions Trading be approached cautiously, viz., on a case-by-case basis, until the Tri-Services Emissions Trading Project has been fully developed and tested.

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COMPATABLE GOALS : DEFENSE AND ENVIRONMENTAL PROTECTION

Edward R. Clark

Department of the Army

US Army Chemical and Military Police Centers

and Fort McClellan

Environmental Management Office

Fort McClellan, Alabama 36205

(205) 238-3019/3758

It is an honor for Fort McClellan to present this paper to this prestigious group dedicated to peace and security. We hope to show how our environmental program at Fort McClellan is not only compatible with that goal, but an adjunct to that goal. We believe that Fort McClellan is symbolic of the Army's environmental program.

Located adjacent to the city of Anniston, Alabama and in the foothills of the Appalachians, Fort McClellan is 80 miles West of Atlanta, Georgia and 60 miles East of Birmingham, Alabama.

The terrain of Fort McClellan generally is mountainous ranging from 305 to 632 meters above sea level. The valley in which the cantonment lies is in an area spotted with rolling hills through which small creeks run through the year. These creeks are fed by springs flowing from underlying limestone strata. Scattered throughout the area are natural wetlands that provide spawning grounds and habitats for fish and wildlife as well as flood control.

The climate, area and character of Fort McClellan make it one of the most picturesque training sites in the United States and has led to its being called the "military Showplace of the South."

Fort McClellan is the home of two major Army schools. Our primary mission is to house and support the training of soldiers. This includes entry level and advanced training for soldiers in nuclear, biological and chemical defense, initial entry level and professional training of Military Police and selected personnel of the Navy, Air Force, Marine Corps and NATO. The secondary mission of Fort McClellan is the training of the US Army

Reserves, National Guard and Reserve Officer's Training Corps units.

Fort McClellan consists of three main bodies of Government-owned leased land. The main installation is 7,570 hectares. Pelham Range, which is used for both live fire weapons and maneuver training, is 8,898 hectares, and the leased Choccolocco Corridor, which provides additional training areas, is 1,795 hectares. As a trustee of 18,400 hectares in the Appalachian foothills, Fort McClellan goals are to properly manage resources that are renewable and conserve those that are not. Another goalist.

Further, we also strive to reduce the environmental insult that is so common when man manipulates the natural environment in pursuit of commonly held needs and values. These broad goals have been developed during the maturation stage of our environmental program and have been finely honed into five specific objectives:

1. To provide environmental education to the widest of audiences with the subject matter tailored to the audience;

2. Prevent material from entering the waste stream. Anything entering the waste stream will be recycled if possible.

3. Actively seek a zero-discharge installation and maintain surface water to the same good biological quality as the water entering the installation.

4. Conserve fossil fuel energy to the highest degree possible to reduce the degrading effect of the natural environment. Further, this recognition is vital to a mobile Army whose readiness is intensely fossil fuel dependent.

5. Preserve the historical character and the cultural resources on Fort McClellan lands.

To summarize the basic tenants of our program, environmental education is the cornerstone that provides support to all our environmental activities. Through this educational process, we must impart an increased awareness of the relationship of our environment to our own welfare. Through an intensely managed education program the Environmental Office has a direct effect on every age group and all disciplines.

An integral part of this program is an outdoor classroom at the Post Elementary School. Through use of this classroom, teachers have gained an increased ability and confidence to teach environmental systems. Fort McClellan has set aside a 50 plus hectares "Environmental Study Area" for the use of local high school and university students. This study area is the result of an interservice support agreement between the US Army and Jacksonville State University.

At Fort McClellan, the Environmental Management Office is the central coordinator for National Environmental Policy Act implementation and compliance. The Environmental Management Office aids the project proponet in development of necessary environmental documentation. For the past five years, the installation has been accumulating data so that adequate assessments and statements can be prepared in a timely manner.

It is our contention that NEPA did not intend for agencies to develop reams of paper in analysis of the environment. We believe the intention of NEPA is to quickly get to the point of conflict between the proposed project and the affected environment. Therefore, we extensively use the 28 categorical exclusions developed by the Department of the Army. The US Army Training and Doctrine Command Form 161-R provides a quick, concise method to insure consideration of the affected environment without lengthy paperwork.

There are times the categorical exclusions do not fit the project. Using a multi-disciplined approach, Fort McClellan coordinated the Environmental Assessment entitled, "Proposal To Construct A Chemical Decontamination Training Facility". We invited the U.S. Army Chemical School to discuss the concept with the Battelle Memorial Institute, the Alabama Department of Environmental Management Chiefs of Air, Water and Hazardous Waste and the Jacksonville State University Archaeologist. Through this meeting, we defined the issues involved, and Battalle began to develop a design concept. With the concept developed and the potential environmental impacts identified, we published our Environmental Assessment in the Federal Register, because of potential national concern.

The Fort McClellan Public Affairs Office arranged TV, radio and newspaper interviews to fully discuss the project locally. At the end of 30 days, we held a meeting at Fort McClellan that included the Post Staff, the Mobile District Corps of Engineers, Battelle, EPA Region IV Offices of Water, Air, Federal Facility Coordinator, the Alabama Department of Environmental Management Offices of Air, Hazardous Waste and Water. The Calhoun County, Health Department, and the City of Anniston. There was a candid exchange of views; everyone agreed it was a proper but daring way to discuss a project.

Through this process a dialogue was established with the community, the proponent and the regulatory agencies. The result of this effort is a project that has gone through 90% design with no public objections or unfavorable interagency comment. NEPA has never hampered our military mission nor slowed any of our projects.

NEPA means good planning, and this is where conflict resolution must begin. For example, it is obviously an expensive burden to conduct site-specific archaeological surveys for every project. Our solution was to develop a model that could predict the likelihood of significant archaeological data. We contracted with the University of Alabama to survey 30 random grid squares. From this survey we can predict what may be found on the remainder of our 18,000 hectares. For those sites with a high probability of containing significant archaeological data, a specific site survey will be conducted by the Professor of Archaeology from Jacksonville State University.

The problem with NEPA is this: the acquisition, management and analysis of environmental data at Army Facilities is difficult, given the time constraints placed on the analyst and the resources available. To improve the data base and efficiently manage and analyze environmental data within these constraints, Fort McClellan, in conjunction with the US Army Construction Engineering Research Lab, has purchased a microcomputer system. This system has many environmental management tools already incorporated in a pilot mode. The 16 bit microprocessor will support multi-terminal use, ie., Environmental Coordinator, Master Planner, Forester and Land Manager. The data has been loaded by the US Army Construction Engineering Research Lab. Some of the data already digitized is Geology, Archaeology, Soils and Wetlands. Through the efficient use of technology, the decision-maker will have more exact data upon which to make crucial decisions, affecting our environment without being constrained by labor-intensive methods.

With 18,400 hectares and 17,000 individuals responding to the environment, we have had our problems and will continue to have problems. The handling of waste motor oil presents disproportionate problems to both operators and the environment. When spills occur, the cumulative effect often belies its significance in the eyes of the operator. Additionally, this represents an unusual economic burden for the requirement to clean-up the small spill. Without due recognition and appropriate response, the small spill can become the nemesis of any large organization.

In 1982, Fort McClellan awarded a contract to install underground waste oil storage tanks at all oil-using facilities. The underground tanks will minimize potential spills. The storage tank system has a catch basin that can be maneuvered under the crankcase of any type vehicle. When the oil is changed, it goes into a catch basin connected to underground oil storage tanks, thus precluding the probability of the small spill. Quarterly testing of underground tanks will reveal leakage. Yearly, a contract will be let to sell the accumulated oil.

In an effort to identify and protect wetlands, color infrared imagery was completed in 1979. The second phase, on-the-ground confirmation was begun in the fall of 1981. In coordination with the Regional Office of the National Wetlands Inventory, US Fish and Wildlife Service, the mapping of the installation wetlands is now complete. Phase three is the publishing of a field guide that will allow non-botanists to survey prospective project sites to determine their wetland status. This survey and series of studies will be used by Fort McClellan for an ongoing effort to protect the wetlands.

The installation sanitary landfill has had a turbulent history. In 1979, the Alabama Department of Public Health threatened to close the facility. This had the potential of disrupting the military mission of the installation. Fort McClellan contracted with the Alabama Geologic Survey to assess potential alternative sites.

Based on the findings, Fort McClellan requested Army pollution abatement funds to relocate the landfill to an environmentally acceptable site. Coordination was accomplished with the Solid Waste Division of Alabama Department of Public Health and preliminary approval was granted for the new site. Contractors drilled test wells and the site was found to have shallow bedrock and water. Efforts to upgrade the existing site were producing good results, but investigations for a new site continued.

In 1980, The State of Alabama was sufficiently impressed with the corrections at the existing site to issue an operating permit. That same year, Alabama Geological Survey located an acceptable, but small site for future landfill use. Due to the acceptability of corrective actions, current plans are to continue use of the existing landfill and hold the new site identified by Alabama Geological Survey for future use. In retrospect, the computer discussed earlier could expedite the search for an alternative site.

Fort McClellan is currently working with the Corps of Engineers on the acceptability of a solid waste incinerator. If the incinerator proves to be effective, the project will greatly reduce the amount of refuse entering the new smaller site, while providing an energy source for the installation.

The generation and handling of hazardous waste is another problem. If hazardous wastes cannot be disposed of on the installation, then an environmentally designed hazardous waste storage facility is the cornerstone of management. With such a facility, hazardous wastes are manageable.

Fort McClellan has constructed one hazardous waste storage facility for PCBs and a second building is programmed for FY 84. However, current thought within the defense community calls for the Defense Logistics Agency to build a hazardous waste storage facilities.

In June 1983 Fort McClellan sponsored an on-site oil and hazardous material handling storage and spill class for users, operators and managers. The education of these groups should reduce the spill potential throughout the installation.

One of the largest potential contributors of toxic chemicals into the environment has traditionally been from Pest Control operations. Implementation of an integrated pest management program not only significantly reduces the amount of chemicals used to control pests, but also dramatically increases the efficiency and effectiveness of a pest management program. In 1981, a professional Entomologist was assigned to the Pest Control Section, Directorate of Engineering and Housing. He was the first professional Entomologist employed at Fort McClellan. The existing pest management program was then expanded to include formal inspections of dining facilities, service clubs and other food establishments to ascertain pest populations. Pesticides are a short term treatment for the symptoms, not a long term cure for the disease.

Primary emphasis has been placed on increased sanitation and elimination of harborages through structural modification. All wooden storage shelves have been removed from dining facilities and replaced with movable stainless steel shelves. When pesticides are used, appropriate dosages and advanced application procedures reduce environmental insult.

The increased emphasis on education, better sanitation, elimination of harborages and increased training for Pest Controllers have led to a more effective, less labor and spray-intensive pest management program. Personnel who handle or dispense pesticides or herbicides are trained and re-certified bi-annually.

A pesticide waste water facility was procured in 1982 as a Research and Development project through the US Army Bio-Medical Research and Development Laboratory at Fort Dietrich, Maryland. The concept is to recycle pesticide waste water through carbon columns and use that water as a diluent. The system is expected to reduce the pesticide residues entering the storm sewer system.

In the U.S. alone, soil is being eroded at the rate of 202.94 tons per second. In cooperation with the US Soil Conservation Service and using the universal soil loss equation, Fort McClellan documented the average loss of 280 tons of soil per year on unvegetated slopes. Steep slopes, easily erodable soils, intense rainfall and other natural man-made conditions have combined to cause soil erosion problems at Fort McClellan. This represents loss of training lands and less paramount concern to both environmentalists and military planners.

In 1982, the Environmental Management Office contracted to have 37 critically eroding acres hydroseeded. Although hydroseeding is not a new technology, it had never been used at Fort McClellan. The cost of $1,000 per acre also included extensive reshaping.

After the hydroseeding, again using the universal soil loss equation, an average of 99.81% reduction of erosion had been realized. These startling figures prompted an investigation of the cost-effectiveness of purchasing a hydroseeder. Our cost comparisons show that an in-house ability to hydroseed will reduce the cost by 50%. The amortization of the hydroseeder is 2.76 months.

Based on these figures, Fort McClellan submitted a request for funding for a hydroseeder to the TRADOC Quick Return On Investment Program Coordinator. We received funding in July 1983 and received the hydroseeder in August 1983. We have forwarded our QRIP documentation to several other installations and hope they will be as successful at combating erosion as we feel we have.

There are many environmental problems of a serious nature that we, as people are faced with. The Department of Defense is trustee of large and ecologically diverse public lands. We must do our part in solving the environmental problems related to that trusteeship. The point of beginning for the problem solving process is at the installation level. We well realize the earth is a planet of finite resources and because of these and many other equally important factors, it is the responsibility of not only the installation, but the individual as well that we attempt to solve these problems.

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ENVIRONMENTAL AND ENERGY AUDITS OF AIR FORCE GOVERNMENT OWNED-CONTRACTOR OPERATED INSTALLATIONS

Brian J. Burgher
Joshua D. Margolis
Doris E. Sanders
JRB Associates
a Company of Science Applications, Inc.
8400 Westpark Drive
McLean, Virginia 22102
703-821-4600

ABSTRACT

Environmental and energy audits conducted for the Air Force Systems Command, Aeronautical Systems Division (ASD) by JRB Associates of McLean, Virginia resulted in substantial environmental benefits and identified opportunities for energy and material conservation and recovery. This effort has allowed ASD to target resources, substantiate funding requests, develop remedial strategies and track progress of environmental and energy management activities. This paper presents a review of the study completed for ASD in October, 1983.

INTRODUCTION

The concept of conducting environmental audits to assess regulatory compliance at industrial facilities has recently been receiving attention by both government and industry. Audits have become popular in direct response to the array of environmental regulations with which facilities must comply and the potential for fines resulting from non-compliance As a preventive management tool, environmental audits help to eliminate "surprises" which are costly, can damage public image, and hinder facility operations.

The Air Force Command (AFSC), Aeronautical Systems Division (ASD), recognizing the benefits of environmental audits, embarked on an audit program for its fifteen (15) Government Owned-Contractor Operated (GOCO) industrial facilties. The principal driving forces behind ASD's decision included:

- Environmental regulations applicable to GOCO's
- DOD directives which require assessment of compliance
- Public relation impacts on facility operations
- Cost and liabilities associated with environmental damages

The ASD audit program went a step further than conventional environmental audits directed at regulatory compliance. They included an investigation of opportunities for conserving, reusing or recycling material and energy resources in industrial plant operations. This additional component was directed at complying with internal DOD directives and reducing expenditures for energy and new raw materials.

- Machining and milling
- Metal surface finishing
- Painting and stripping
- Degreasing and cleaning
- Engine fueling and testing
- Engine overhaul
- General facility maintenance

These manufacturing activities involve operations which are subject to environmental regulation and/or were potential sources of hazard to human health or the environment. Common environmental management activities at the fifteen GOCO's, and regulations which cover such activities consist primarily of:

- Hazardous waste management (RCRA, CERCLA, State regulations)
  - generation
  - transportation
  - storage in tanks, containers, piles, and surface impoundments
  - land disposal
  - incineration
- Air emissions (CAA, state regulations)
- Water discharges (CWA, state regulations, SPCC)
- PCB use and disposal (TSCA)
- Underground fuel storage (SPCC, state, and local regulations)

APPROACH

In preparation for the reviews of the Air Force industrial plants, a methodology was developed which was successfully used for each of the fifteen industrial reviews. This methodology employed six basic steps, graphically displayed in Figure 1-2, and summarized below.

Step One: Initial Review of Federal, State and Local Laws and Regulations

To identify regulatory programs applicable to each plant and to determine compliance requirements, the initial review began with an examination of Federal, state, and local laws and regulations; Air Force/Department of Defense directives; and Executive Orders. The result of this examination of regulations and directives was the identification of basic information needed from each facility during the preliminary data acquisition step to determine its compliance with regulations or directives. It also established the basis for cooperation with state and local governments by identifying all requirements at those levels.

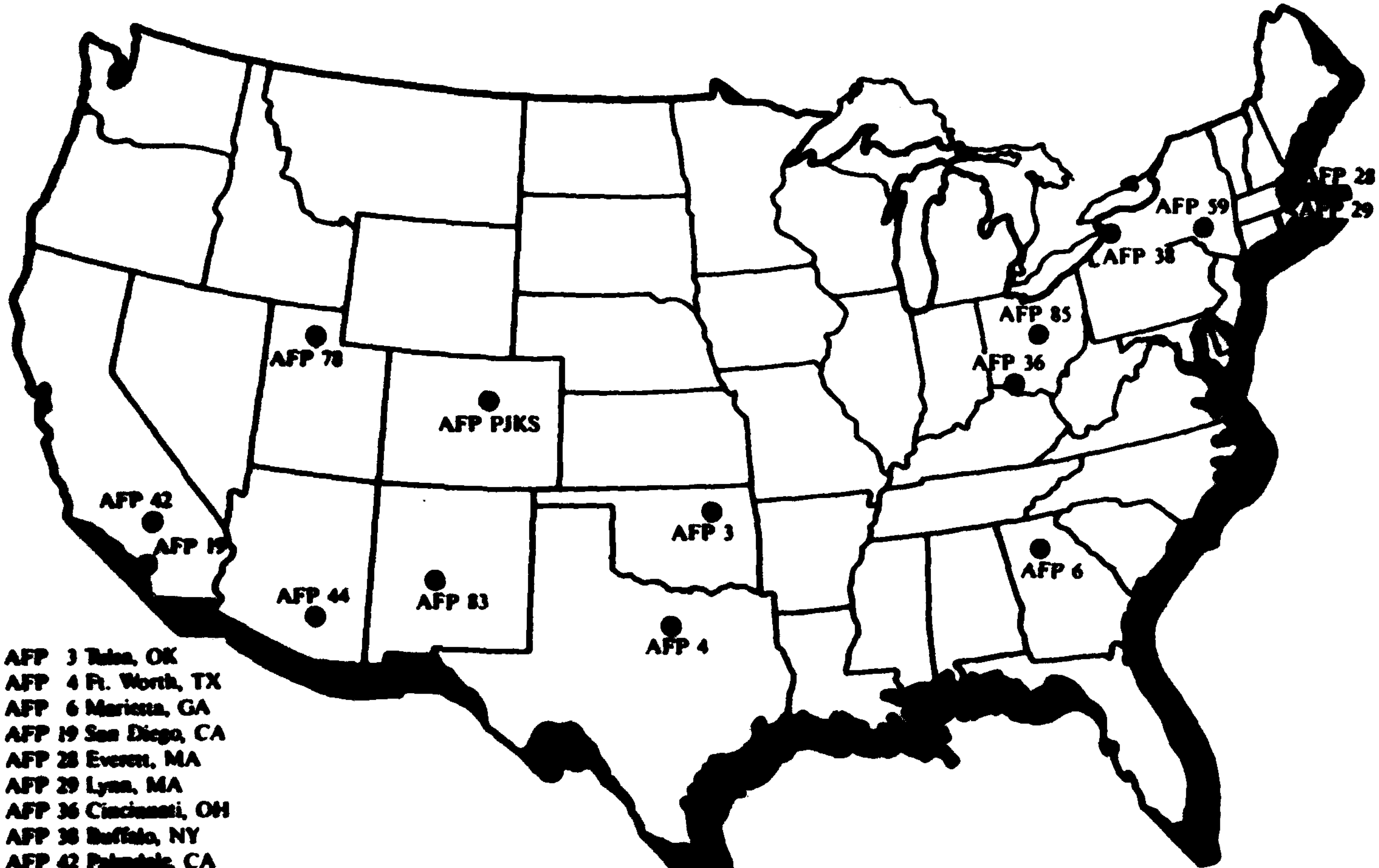

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Figure 1-1. Locations of GOCO Facilities

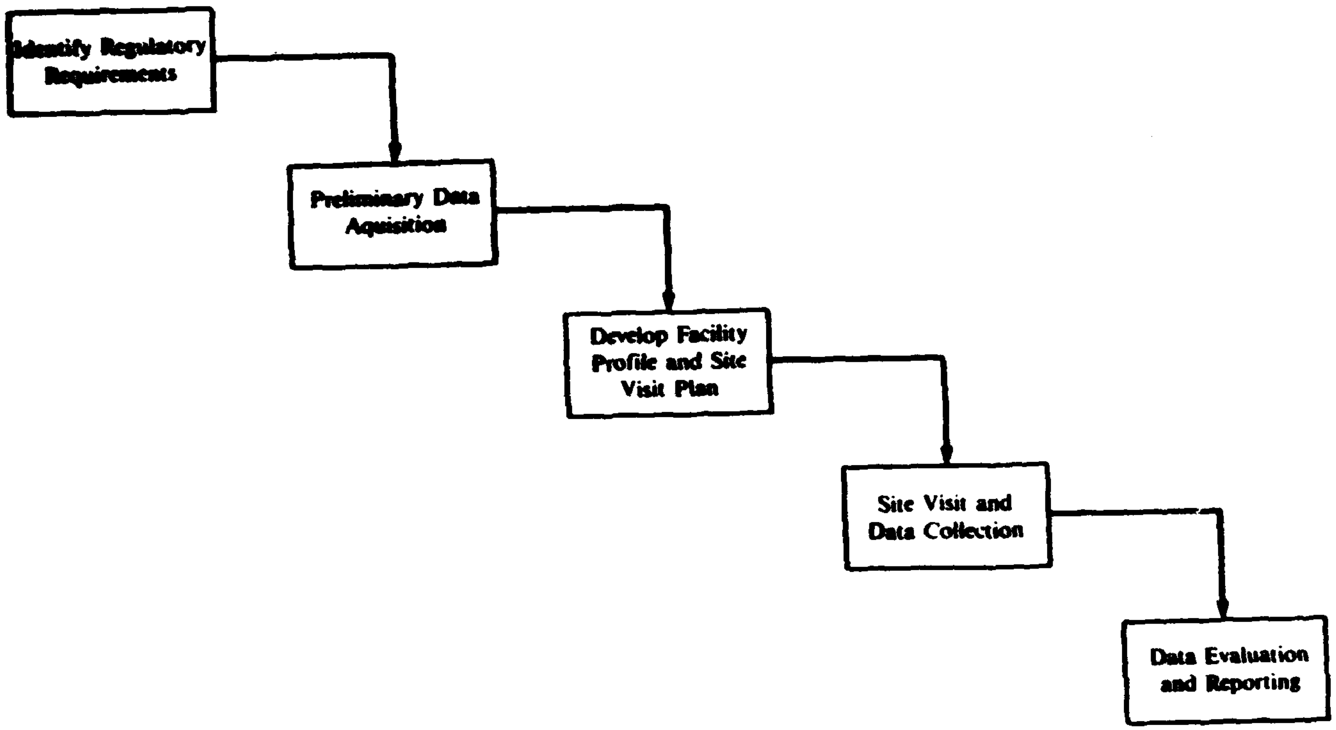

Figure 1-2. Steps in Conducting Environmental Compliance/Energy/Resource Conservation Reviews

Step Two: Preliminary Data Acquisition

Acquiring basic information in advance familiarized the audit team with the plant's operations, thus enabling proper preparation for the site visit. This proved to be the most cost-effective way to plan the site visit, as it helped identify which areas of the facility and/or its operations required visual inspection, and where data gaps existed. As a result of the acquisition, organization, and analysis of this information, the audit team prepared a plant profile and site visit plan which structured the site visit and ensured an efficient, cost-effective on-site review.

Step Three: Develop Facility Profile and Site Visit Plan

A facility profile and plan for the site visit were developed based on the information gathered during the preliminary data acquisition step. The facility profile included summaries of plant operations, regulations which applied to these activities, potential problem areas, particular data gaps of areas requiring detailed investigation, listing of iste personnel to be interviewed, and maps, figures and descriptions of the facility. The site visit plan served as a guide for the site visit. Together, they allowed the team to structure and conduct the site visit in an efficient and expedient manner, with minimum disruption of facility activities.

Step Four: Site Visit and Data Collection

The purpose of the site visit was to survey the physical elements and processes of the facility, to review pertinent records and files, and to conduct personnel interviews with key staff at the facility. It also allowed members of the team to informally observe practices of the facility, which provided valuable insights into day-to-day plant operations and management. The compliance profile and site visit plan served as guides for this on-site review.

The sequence of activities conducted during the site visit included:

1. Introductory briefing.

2. Personnel interviews.
3. Record reviews.

4. Facility and operations surveys.

5. Exit briefing.

This sequence of site visit activities were found to effectively collect information needed to evaluate environmental compliance and potential hazards while keeping facility personnel informed of findings throughout the process.

Step Five: Data Evaluation and Reporting

A report was prepared for each industrial plant based on an evaluation of the information gathered in the previous steps. These reports assess environmental compliance, additional hazard areas, and identify energy and resource conservation activities and opportunities. They also serve as a planning tool for ASD and plant staff to provide for future needs in these areas.

RESULTS

In October of 1983, ASD completed environmental audits for its fifteen GOCO facilities and had an opportunity to evaluate the results. In review, this program met ASD's primary objectives which encompassed:

- o Summary of facility operations
- o Assessment of environmental compliance and potential hazard areas
- o Recommendation of improved environmental management
- o Identification of opportunities for material and energy conservation and recovery.

As a result, ASD was able to provide an assessment and operational plan to meet the immediate AF requirements specified in AF Directive 78-22, which outlined an environmental and energy program directed at environmental compliance, reduction in liabilities and conservation of resources.

In addition to this immediate benefit of their audit program, ASD has realized a long list of benefits including:

- o Improved relations with regulatory agencies
- o Improved public relations
- o Improved compliance with applicable environmental regulations
- o Better understanding of facility operations
- o Opportunities for significant cost savings through energy and materials conservation.

ASD is also anticipating experiencing the following benefits through continued monitoring of their program:

- o Greater protection of human health and environment
- o Reduced environmental liabilities
- o Reduced costs for clean-up of environmental contamination
- o Reduced costs for energy and raw materials

All of these benefits of ASD's newly developed program are the direct result of greater management understanding and control of environmental and energy operations at the fifteen GOCO facilities. This has allowed ASD to implement a follow-up program which has as its core the ability to:

- target resources
- substantiate funding requests
- plan and develop remedial strategies
- track progress of activities.

Thus, the success of ASD's environmental and energy audit program has helped to begin the development of an environmental/energy management program which is based on two major tenets:

1. Reduction hazards to human health and environment

2. Reduction in expenditures

This course is one being developed with greater frequency across the country to avoid potential backlashes as a result of inadvertant environmental and energy mismanagement.

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STRATEGIES FOR PREPARING AND SUBMITTING A PART B APPLICATION FOR A DOD FACILITY

By Wayne K. Tusa

As you are all aware, the United States Environmental Protection Agency (EPA) has issued regulations to ensure the protection of human health and the environment through the appropriate management of hazardous wastes under Subtitle C of the Resource Conservation and Recovery Act of 1976 (RCRA). Those regulations require most facilities that treat, store or dispose of hazardous waste to obtain a RCRA permit. The application for this permit consists of two parts, Part A and Part B. Facilities in existence before November 1980 were required to submit the Part A application by November 19, 1980. These facilities were granted "interim status" under the regulations, which permits them to continue operations until final administrative action is taken on their permit. This requires the submittal of a detailed Part B permit application. The permit application must contain sufficient information to assure EPA that the facility design, operation and proposed closure and post-closure plans will satisfy the applicable permitting standards.

The Agency has called and begun to review several hundred permit applications in recent months. Close examination of how that process has worked

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Mr. Tusa is the Director of the corporate office of Fred C. Hart Associates, Inc. in New York City, located at 530 Fifth Avenue, New York, New York 10036, (212-840-3990).

to date has provided important clues with respect to streamlining the receipt of a Part B permit for any facility currently preparing a permit or expecting to be called. The purpose of this presentation is to provide a brief summary of the contents of a Part B application, to identify the major goals which should be held by the applicant and the permit writers and to provide some insights on the lessons learned so far in the Part B process.

Regulations and Applicant's Goals

To put the following comments in context, it is necessary to understand in general what the regulators' goals are in reviewing the permit application and in preparing and issuing a facility permit. As well, in retrospect, it is of interest to understand the most appropriate set of goals which should be adopted by the applicant in preparing the permit application and in completing the application public record. For the permit writer or regulator, the goals are quite clear:

- To assure that all prescribed information is provided
- To assess whether the site will release hazardous compounds in concentrations that might harm human health or the environment or which might violate applicable standards
- To ascertain apparent level of compliance and the overall resources dedicated to the RCRA program implemented to date by the applicant
- To select the most appropriate set of general and specific permit conditions required based upon the information provided

The applicant's goals are less clear and can be more flexible. In general, however, the applicant shoud seek:

- To submit all necessary information
- To demonstrate compliance with all applicable regulations
- To provide substantial documentation defining the level of hazardous releases that might occur and the relative risks associated with those releases
- To leave the impression that a comprehensive well managed program is and has been in place
- To provide the data in a highly professional and well organized format
- To provide an adequate level of detail to result in favorable decisions by EPA permit reviewers in those areas subject to "best engineering judgment"
- To minimize compliance costs over the life of the permit
- To prepare a document suitable for public consumption for those portions of the permit not covered by a claim of confidentiality

The Potential Complications Associated With DOD Facilities

Preparation of the Part B application for a DOD facility can be more complicated and time consuming than a similar permit application for a privately owned facility for a number of reasons.

First of all, DOD facilities tend to be large and complex. The hazardous waste management system itself may also be extensive and complicated. Consequently, the data gathering and procedures implementation tasks may be complicated. This may hold true even at installations having only relatively simple permitting requirements, such as an installation having storage facilities only, since the entire on-site waste management system needs to be described as background material.

A second issue may relate to the division of hazardous waste responsibilities at the installation. Different activities and different tenants result in differences in day-to-day operations, thus complicating data collection and the development of consistent management procedures to which the applicant can commit to in the permit application.

Another issue relates to obtaining timely support up through the chain-of-command. This can be particularly frustrating if the intent of the application is not well understood by management personnel and consequently, either adequate resources are not made available or decisions on key issues are not made in a timely manner. For example, in our experience, it is not uncommon to find, in both the public and private sectors, in the data collection process that procedures in place during the interim status period are not likely to be adequate under Part 264 regulations. This requires the definition of appropriate procedures and the description of these procedures in the appropriate segment of the application, all of which cannot be expeditiously completed if timely decisions are not made.

A similar issue relates to the budgeting process. Ideally, when any applicant submits the Part B application, there should be no outstanding areas of non-compliance. If during the course of preparation of the application, it is determined that specific capital expenditures are required, it may be difficult to complete the design, budgeting and construction process with the generally limited time available to complete the Part B application.

A last issue relates to the types of activities that commonly occur at DOD facilities. It is generally quite clear that EPA's regulations were not written with DOD type installations in mind. There are a variety of reasonably common operations that occur at DOD installations which are not or are only partially covered by the EPA regulations. Typical examples include popping furnaces and open burning.

Contents of a Part B Application

A typical Part B application would include the following:

A. Part A Application
B. Facility Description
C. Waste Characteristics
D. Process Information
E. Monitoring Systems
F. Procedures to Prevent Hazards
G. Contingency Plan
H. Personnel Training
I. Closure Plans, Post-Closure Plans, Financial Requirements
J. Other Federal Laws

Other sections that might be included are:

K. Evaluation of Potential Emissions
L. Suggested Permit Conditions
M. Compliance Checklist

Lessons Learned

In that context one can begin to identify some of the key lessons that have been learned to date by the involved parties. Perhaps the first of these relates to how one gets called for a Part B permit in the first place. Broadly speaking, EPA (and the states) have been calling "major facilities." While the procedures vary on a state-to-state and region-to-region basis, a potential major facility is any facility that is large, is a land disposal or incinerator facility, is significantly out of compliance with the interim status requirements, is a facility that poses a high risk to human health or the environment and/or is highly visible.

A second lesson is that the RCRA permit is the cornerstone of the entire regulatory system. At this point in time, the regulatory agency completes, often for the first time, a full evaluation of whether the facility is in compliance with the interim status regulations. Additionally, the permit will require designs and operating procedures which are consistent with the applicable regulations for the full ten year permit period.

Consequently, the level of detail required in the permit application typically exceeds by far that which has been requested under many water, wastewater and air permit programs. The technical requirements are more complex and detailed and as a result the permit application itself tends to be lengthy, ranging from 100 to 500 pages in length.

As a result, the permit application tends to be costly. Typical costs to an applicant include not only administrative, technical and legal costs but also capital costs for facility improvements and increased operating costs to maintain compliance. The permit application may also require very detailed technical analyses, such as test burns, groundwater modeling, exhaustive chemical analyses, etc.

The complexity of the Part B process and the applicable regulations inevitably leads to uncertainties. Part B's are new to many, including some of the permit writers. The inter-relationship between the states and EPA can be confusing, state level RCRA regulations typically differ in coverage, standards and procedures even if the program has been deemed "equivalent and consistent." The time frame over which the application is prepared and reviewed also creates inherent uncertainties since the regulations have been in a state of constant change. As well, there are often technical gaps in the personnel available to permit writers on specific aspects of individual permits.

One of the major uncertainties among applicants seems to relate to whether a Part B is really needed at any one facility, or what hazardous waste units need to be covered in a facility-wide Part B application. Typical examples include wastewater treatment facilities, recycling/recovery facilities and storage facilities.

Once one is quite confident that a particular facility needs a Part B application, one lesson learned is not to assume that the facility meets all interim status requirements since the facility may have undergone a state or federal inspection. This tends to be a major problem for two reasons. The first is that many of the pre-Part B inspections have been surficial inspections only, i.e. does a facility have a contingency plan rather than does that contingency plan meet the Part 264 requirements. As a consequence, at a great number of facilities, the existing interim status compliance plans (inspection, contingency, training, closure, etc.) are often inadequately detailed for the purposes of the Part B application.

The second reason relates to the adequacy of the existing facility to meet the design and performance standards of the interim status and Part 264 regulations. As a consequence, capital expenditures and/or operational changes may be required to bring the facility into compliance before the application is submitted. Assuming that this is technically possible, the applicant presents a much stronger case to the regulators and to the public relating to its attempts to meet the mandates of the law. Typical examples might relate to incompatible waste storage areas in container storage facilities, lack of emergency response equipment, inadequate groundwater monitoring facilities, etc.

Once the applicant understands the facility's relative state of regulatory compliance, an additional lesson learned relates to taking full advantage of EPA's help and how best to obtain that assistance. The applicant has a wide variety of choices including obtaining access to the numerous relevant technical resource documents, utilizing the RCRA/Superfund Hotline (800-424-9346), developing a one-to-one relationship with the assigned permit writer and taking advantage of pre-application meetings and EPA, state and contractor sponsored training sessions. Additional useful approaches include having the permit writer visit the site early in the six month time frame, having the permit writer review available interim status documents and draft sections of the Part B permit application.

Once the applicant understands the relative complexity of the job at hand and the degree of assistance he can obtain from the permit writer, the applicant must develop a strategy and schedule to assure that the permit application will be in on time. EPA has the authority to revoke a facility's status if the application is not received on time and/or to invoke financial penalties. As well, the applicant needs to be doing everything within reason to maintain credibility with the regulatory agency.

While preparing the application it would also be a mistake to take a short-term view for a number of reasons. One of these relates to the current definition of a minor permit modification. At this time most modifications to the Part B permit are classified as major and at a minimum would require a public hearing. As a result, where possible all permits should identify and incorporate expected changes.

It is particularly important as well to recognize that once issued, the permit will control the effective costs of operating the hazardous facility covered by that permit. A high quality permit application would demonstrate to the agency permit writer the applicant's commitment to regulatory compliance and an argument could be made that the resulting permit conditions would be less stringent (and costly) than those proposed for an acceptable but less well managed (and riskier) TSD.

The last point brings to mind another lesson learned to date. The permit writer is human, with all the strengths and weaknesses representative of that race. Regardless of the need for consistent federal and state regulations and permit conditions, it is the permit writer that the applicant must first satisfy. On that basis, it behooves the applicant to identify early-on in the process what specific details the permit writer wants to see, in what format the data should be presented, and how flexible the assigned permit writer will be to utilizing existing textual materials, interpreting the specific portions of the regulations, etc.

This brings up another valuable point: the applicant should take advantage of opportunities for variances or alternative regulatory interpretations where they might logically apply to the specifics of any one site. The regions and most of the states appear to have considerable flexibility in how stringent their interpretation of the specific requirements may be.

Conversely, during the process it is also important to monitor the permit writer for procedural correctness. Since the permit writer is human he can make mistakes, and in some instances it may be advantageous to the applicant to demonstrate his or her detailed understanding of the regulations by pointing out a more precise interpretation of these regulations.

Once the application is completed, there are a number of additional lessons learned which can make the whole process less painful to the applicant. These include, for example, not forgetting to claim confidentiality if appropriate on the actual submission. Another relates to not informing EPA of any new information or circumstances that occur while the process is on-going. Again, this relates primarily to maintaining credibility with the regulatory agency and the general public.

It is also important to assure that the permit application alone does not constitute the entire record. Where possible all communications should be substantiated in writing.

This becomes crucial when one recognizes that receipt of a Part B permit requires participation at a public hearing where all of your "hazardous" operations will be exposed to public scrutiny. In preparing the application and the record, it is crucial to present all the data in a format understandable to a layman. The public too must be satisfied and your arguments, your assessments of risks and your conclusions must be acceptable to the community.

It is also important to note that the public hearing and the subsequent regulatory decisions do not constitute a final decision if the permit application is denied or is extraordinarily rigorous. An applicant has the right to appeal based upon the reasonableness of the decision as it relates to what data is contained in the application record.

Summary

The Part B process is complex, uncertain and inherently subjective. While the level of uncertainties is decreasing, the applicant can minimize the uncertainties by aggressively managing the process. The applicant must plan his strategy, pay particular attention to details and follow through daily if necessary. The long-term cost savings alone should justify the increased attention given to management of the Part B application process.

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AUTHOR RESUME SUMMARY

Mr. Wayne Tusa is the Director of Fred C. Hart Associates, Inc.'s corporate office in New York City. Fred C. Hart Associates, Inc. is an environmental and engineering consulting firm with a nationwide reputation in solid and hazardous waste management. Mr. Tusa's experience in Part B applications relates to the preparation of four Part Bs at various Army and Navy facilities, as well as several additional Part Bs for the private sector.

Mr. Tusa is currently Vice-Chairman of ASCE's Solid Waste Committee and Chairman of the Metropolitan Section's Environmental Committee. Most recently, Mr. Tusa served as Chairman of the Society's Hazardous Waste Committee and Vice-Chairman of the Residuals Management Committee.

AD-P004 140

ASSESSMENT OF ENVIRONMENTAL COSTS
AT
ORDNANCE ACTIVITIES

Prepared by:

Linda J. Lay
Michael F. Larson
Pamela G. Clements

Ordnance Environmental Support Office
Indian Head, Maryland

20 March 1984

ASSESSMENT OF ENVIRONMENTAL COSTS AT ORDNANCE ACTIVITIES

Introduction

Environmental protection programs, necessitated by governmental regulations, require manhours and materials to administer. This costs money. The purpose of this study was to determine the magnitude of expenses associated with the programs mandated in the Navy's Environmental and Natural Resources Protection Manual; OPNAVINST 5090.1 of 26 May 1983.

Background

In the past, Naval Sea Systems Command has experienced difficulty in identifying expenditures specifically incurred for implementation of environmental regulations. This problem is due to the fact that support for environmental services has lay hidden in other operating functions. As a result, an effort was directed toward establishing a budget line item to satisfy this requirement.

Approach

To establish a budget line item, the magnitude of the expenses necessitating funding required investigation. The approach selected to conduct this investigation involved estimating the cost to a typical government facility of complying with the Navy's Environmental and Natural Resources Protection Manual (OPNAVINST 5090.1 of 26 May 1983). This manual encompasses all Navy environmental programs.

The Navy's Ordnance Environmental Support Office (OESO), a specialty office working closely with the ordnance community on environmental matters, was selected to conduct this study owing to its familiarity and expertise with ordnance and industrial-type activities and their associated environmental programs.

The Naval Ordnance Station (NAVORDSTA), Indian Head, Maryland was chosen as a typical facility owing to its wide range of DoD industrial operations affected by the environmental programs. NAVORDSTA is a medium sized, light manufacturing activity with a civilian employment of approximately 1,800 people. Most of the workload consists of propellant manufacturing, rocket motor assembly and engineering development for various weapon systems used by the Navy.

Methodology

The OPNAV Instruction 5090.1 was evaluated by assigning individual chapters to OESO personnel with associated expertise. A literature search was performed for documentation governing the environmental impact of DoD operations. This documentation was gathered from the following:

1) Presidential Executive Orders
2) Congressional Legislation
3) Federal Agency Regulations
4) DoD Policy
5) Navy Command Requirements
6) Systems Command implementing instructions

The products of this literature search were directive chains applicable to the individual chapters of the manual. As an example, Chapter 6 generated the following directions as a result of the Clean Air Act.

In order to support a budget line item for an activity level environmental program, it was necessary to demonstrate the cost to an activity of implementing the directive chain. Eleven elements were pre-established and used for Indian Head budgetary application. Many NAVSEA activities share these common elements. Levels of compliance were established and initially applied to the manual on a chapter by chapter basis. At the same time we carefully considered the various waste generating operations at Indian Head. Functional operations were defined based on our familiarity of Navy organization and program implementation at the activity level. Specifically, areas of environmental impact and/or responsibility were determined at the Station. Responsible personnel in these areas were contacted by members of OESO to determine the tasks required to comply with the directive chain. In addition, FY83 forecasted budgets versus actual expenditures were discussed. Elements applicable to the environmental program were added or deleted and the cost estimated at this time.

The sums of the individual chapters were calculated and totaled. This total represents the cost of the Naval Ordnance Station Environmental Program for fiscal year 83.

Findings

The following are our findings based on a chapter by chapter analysis of the manual.

Chapters 1 & 2 discuss the overall responsibility of the Commanding Officer of a Naval facility which infers a "special staff" for an environmental coordinator to administer the overall environmental program for the activity. For the purpose of this report, the administrative costs have been deferred and included as an administrative line item in the various environmental program areas. The administrative costs encompass both managerial and technical functions as well as clerical support.

Chapter 3 discusses the requirements of the Naval Environmental Protection Support Services (NEPSS). NEPSS, as its title implies, is a Navy support organization employed by contract when needed by individual activities. NEPSS support therefore is not an annual activity budget line item; rather it is funded on a task basis. During FY83, NAVORDSTA Indian Head tasked NEPSS to certify the performance of installed air pollution equipment at a one time charge of $65K.

Chapter 4 addresses the requirement placed upon activities by the National Environmental Policy Act (NEPA) which mandates the preparation of Environmental Impact Statements (EIS). Internal Navy requirements include Environmental Assessments (EA) and Preliminary Environmental Assessments (PEA). NAVORDSTA Indian Head prepares PEAs/EAs prior to pilot scale manufacture of specialty chemicals. These environmental assessments collect and consider toxicological and other hazardous properties to insure that the manufacturing effort will be in compliance with environmental regulations. The FY83 cost to Indian Head for preparation of PEA/EAs was $5K.

Chapter 5 addresses Water Pollution Abatement Ashore which includes those measures necessary to prevent and control surface and groundwater pollution from wastewater, dredge and fill operations and surface runoff from Naval Shore Activities. The FY83 water pollution budget for NAVORDSTA, Indian Head totaled $314,100. This total included costs associated with the operation of sewage treatment plants. Specific line items include the cost of administration, sampling, analysis, reporting, operations, maintenance, supervision and training.

Chapter 6 delineates the requirements initially mandated by the Clean Air Act and promulgated through state and regional programs. Individual Navy requirements relative to air emissions are also addressed. Due to the lack of the requirement for an air emissions permit, the air pollution program budget for NAVORDSTA Indian Head is relatively low. During FY83, NAVORDSTA Indian Head air pollution costs included administration, ambient air monitoring, power house stack monitoring, and a one time cost of monitoring ordnance open burning operations. The cumulative cost of this effort was $27,200.

This chapter identifies those cost elements incurred in the day to day operations of an activity waste disposal program. Based on regulations promulgated under the Resource Conservation and Recovery Act (RCRA), Naval activities are required to establish a resource recovery program whenever possible. Chapter 7 deals exclusively with non-hazardous waste. At Naval Ordnance Station Indian Head, non-hazardous solid waste is transported off-station for disposal. The cumulative cost for this effort is $256,694. The major portion of this total is allocated to transportation costs. This transportation line item includes contract hauling and disposal.

Chapter 8 talks to noise pollution. Activities are required to conform to federal regulations established by the Environmental Protection Agency, and state and local laws prescribing maximum permissible noise levels across property lines. Explosive ordnance disposal operations and rocket motor testing are local issues of concern at Indian Head and possible public reaction is a constant consideration of Station management during these operations. As a result of these cooperative concerns for the community, there are currently no local laws or ordinances that inhibit operations. For this reason, no budgetary line item is required.

The next chapter outlines the applicable pollution prevention and abatement regulations for mixing, storage, and disposal of pesticides at Naval shore facilities as required by the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). The Naval Ordnance Station maintains an open-end contract for most pest control work. The Station's contingency plans provide for personnel, facilities, and equipment to be used for a pesticide spill on the activity grounds. The contract cost was $30,000 for fiscal year 1983. Spill control of pesticides is budgeted under the elements of Chapter 13. Waste water discharge of pesticides is covered under the National Pollution Discharge Elimination System (NPDES) addressed in Chapter 5 and disposal of hazardous pesticide waste is included in the cost elements of Chapter 11.

There are two chapters that deal with the Oil Spill Control Program. Chapter 10 accounts for the routine day-to-day costs associated with oil; such as annual maintenance, transportation and routine disposal of petroleum products. The cumulative cost of this effort was $28,500.

Chapter 11 identifies the responsibilities and requirements that are applicable to the control of pollution from the use of hazardous materials and hazardous substances, including hazardous waste. As one would expect, the cost of the hazardous materials program is a major expense of the environmental program budget for any Naval industrial facility. Contingency planning for spills of hazardous materials or waste is addressed in Chapter 13. NAVORDSTA Indian Head has $228,880 budgeted to accomplish the environmental management of hazardous materials and hazardous waste. At Indian Head, the major portion of these funds is expended on incineration of hazardous waste in compliance with the exemption for open burning provided by the Resource Conservation and Recovery Act. It is estimated that the cost of transportation and incineration is $130 per barrel of waste. High disposal cost may be attributed to the sensitivity of the materials associated with ordnance and the accompanying special handling requirements of explosives and propellants.

NAVORDSTA Indian Head is a shore facility and does not support a pier or ships. Those activities which do provide this support, will reflect additional costs for the budget line items expended for Chapter 12, Pollution Abatement Afloat.

The elements of Chapter 13 are concerned with contingency plans to control spills of oil and hazardous substances. Naval Ordnance Station, Indian Head did not have an oil spill in fiscal year 83. The Station uses over 2000 different chemicals and hazardous substances, and the associated clean-up and administrative costs of these materials totaled $89,700.

In general, regulations prohibit transporting material from shore for deep water disposal. Some exceptions are allowed and permits are issued on a case-by-case basis. Weapons and Combat Systems Directorate field activities do not have any known permits even though there is occasional ocean disposal of dredged material. This chapter includes the costs of "burial at sea".

Chapter 15 addresses the requirement for each Naval activity having significant land area, or with natural resources management problems, to prepare a comprehensive natural resource management plan. This plan must include soil and water management, fish and wildlife and outdoor recreational planning. Natural resource management plans should also consider endangered species, wetlands and natural cultural and historic areas. In fiscal year 83, N•val Ordnance Station Indian Head invested $69,446 in accomplishing various elements of this natural resource management objective. Much of the forest management expenses were off-set by the proceeds from the sale of forest products.

Chapter 16 identifies optimum levels of quality and use of industrial and drinking water. The Station spent $488,000 on this endeavor in fiscal year 83. The cost of industrial operations and production of steam contributes to this relatively high figure.

As an incentive for activities, and to increase the effectiveness of the Navy's Environmental Program, the Secretary of the Navy has established the Navy Environmental Protection Annual Awards Program. Chapter 17 outlines submission requirements for this award and delineates the award activity selection criteria. Funding is provided through general administrative costs.

<u>Summary</u>

To recap our findings, the total cost of the NAVORDSTA Indian Head Environmental Program for FY83 was $1,602,520. This represents approximately 1.2% of the NAVORDSTA Indian Head FY83 budget. As one would expect, the most costly regulations, for Naval activities to implement, orignate from the Clean Water Act (CWA) and the Resource Conservation and Recovery Act (RCRA). It is estimated that compliance with regulations mandated by the CWA account for approximately 20% of the total environmental program cost. RCRA compliance accounts for approximately 30%.

Conclusion

Based on the findings of this study, the cost of the environmental program for a medium size Naval industrial activity is unquestionably of sufficient magnitude to support its inclusion as an annual budget line item.

With the environmental emphasis of the past decade and the continuing implementation of associated regulations, the support of environmental protection programs should not diminish and must be considered as a cost of doing business. This fact was reinforced during an EPA Enforcement Staff Conference which was held in January 1984. The purpose of the conference was to discuss agency plans for stepped-up enforcement of environmental regulations. During the conference, EPA Assistant Administrator Lee Thomas remarked "In order for federal hazardous waste mangement statutes to be effective in halting pollution, those governed by the laws must be given a clear message that the costs of violations will exceed the benefits".

Table I. Cost Estimates[1]

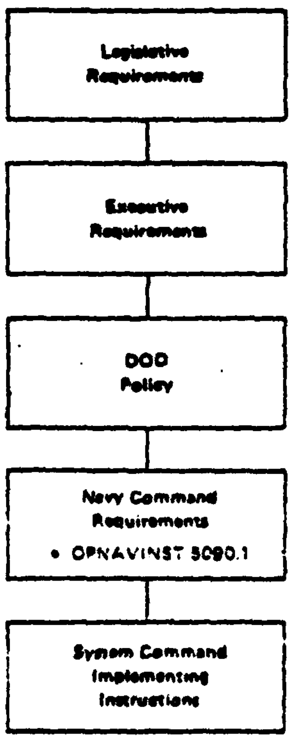
Chapter No.	Title	Cost (FY-83)
1	Policy and General Responsibilities	None
2	Pollution Abatement Program	None
3	Naval Environmental Protection Support Service	$ 65,000
4	Environmental Assessments and Statements	5,000
5	Water Pollution Abatement Ashore	314,100
6	Air Pollution Abatement Ashore	27,200
7	Solid Waste Management and Resource Recovery Ashore	256,694
8	Noise Abatement Ashore	None
9	Pesticide Pollution Abatement Ashore	30,000
10	Oil Pollution Abatement Ashore	28,500
11	Hazardous Materials Environmental Management Ashore	228,880
12	Pollution Abatement Afloat	None
13	Oil and Hazardous Substance Release Contingency Planning	89,700
14	Ocean Dumping	None
15	Natural, Cultural, and Historic Resources	69,446
16	Industrial and Drinking Water Systems	488,000
17	Secretary of the Navy Environmental Protection Annual Awards Program	None
Total costs		$1,602,520

[1]Chapter titles correspond with those in the Environmental and Natural Resources Protection Manual (OPNAVINST 5090.1).

Chapter 1: Policy and General Responsibilities

Typical Elements for Compliance	Indian Head Budget Element	FY-83 Cost
Environmental Coordinator		—
Total cost		$ 0

CHAPTER 1. POLICY AND GENERAL RESPONSIBILITIES
DIRECTIVE CHAIN



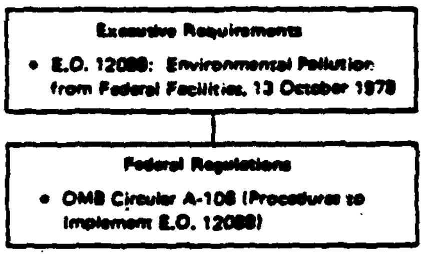
Chapter 2: Pollution Abatement Program

Typical Elements for Compliance	Indian Head Budget Element	FY-85 Cost
Environmental Coordinator, program and project planning		—
Total cost		$0

Chapter 2: Pollution Abatement Program

Typical Elements for Compliance	Indian Head Budget Element	FY-83 Cost
Environmental Coordinator, program and project planning		—
Total cost		$ 0

CHAPTER 2. POLLUTION ABATEMENT PROGRAM DIRECTIVE CHAIN



Chapter 3: Naval Environmental Protection Support Service

Typical Elements for Compliance	Indian Head Budget Element	FY-83 Cost
Certify performance of installed air pollution equipment (coal conversion; one-time charge by NEESA).		$65,000
Total cost		$65,000

CHAPTER 3. NAVAL ENVIRONMENTAL PROTECTION SUPPORT SERVICE – DIRECTIVE CHAIN

Legislative Requirements

- Clean Air Act. 42 U.S.C. 7401
- Federal Water Pollution Control Act. 33 U.S.C. 1251
- Solid Waste Disposal Act. 42 U.S.C. 6901

Executive Requirements

- E.O. 11523: National Industrial Polution Control Council
- E.O. 12088: Purpose and Policy of Clean Air Act
- Federal Water Pollution Control Act
- Solid Waste Disposal Act

DOD Requirements

- DOD Inst 4120.14: Implementation of Policies Provided by E.O. 12088
- DOD Directive 5100.50: Use of DOD Resources in Protecting and Enhancing Environmental Quality
- DOD Directive 6050.1: DOD Administration of National Environmental Policy Act of 1969

Navy Requirements

- SECNAVINST 6240.6E: DON Environmental Protection and Natural Resources Management Program: 18 August 1977
- OPNAVINST 5090.1: Environmental and Natural Resources Protection Manual: 26 May 1983

NAVMAT Instructions

- 6240.4A: Naval Environmental Protection Support Services: 13 June 1974

Chapter 4: Environmental Assessments and Statements

Typical Elements for Compliance	Indian Head Budget Element	FY-83 Cost
Prepare environmental documents	Preliminary Environmental Assessments/Environmental Assessments	$5,000
Total cost		$5,000

CHAPTER 4. ENVIRONMENTAL ASSESSMENTS AND STATEMENTS – DIRECTIVE CHAIN

Legislative Requirements

- National Environmental Policy Act
- Endangered Species Act, 28 December 1973

Executive Requirements

- E.O. 11472: Cabinet Committee on the Environment and the Citizens' Advisory Committee on the Environment; Establishment: 29 May 1969
- E.O. 11541: Cabinet Committee on the Environment, Termination and Reassignment to the Domestic Council: 1 July 1970
- E.O. 11514: (Amended by E.O. 11991 24 May 1977) Protection and Enhancement of Environmental Quality; Responsibilities of Federal Agencies Under NEPA
- E.O. 12088: Federal Compliance with Pollution Control Standards: 13 October 1978
- E.O. 12316: Response to Environmental Damage; National Contingency Plan: 14 August 1981
- E.O. 12291: Federal Regulation, Cost/Benefit Analysis, Impact Analysis: 17 February 1981

DOD Requirements

- DOD Directive 6050.1: NEPA, Policy, Responsibilities, Guidance on Administration of: 30 July 1979
- DOD Directive 5100.50: DOD Committee on Environmental Quality, Establishes; DOD Resources, Use of: 24 May 1973
- DOD Directive 6050.7: NEPA, Responsibilities for Compliance with: 31 March 1979

Navy Requirements

- SECNAVINST 6240.6E: Environmental Protection and Natural Resources Management Program, Assignment of 18 August 1977
- OPNAVINST 5090.1: Environmental and Natural Resources Protection Manual: 26 May 1983
- NAVMATINST 6240.4A: Navy Environmental Protection Support Service: 13 June 1974

NAVFAC Instruction

- 6240.3A: Pollution Control Report; Responsibility and Guidance: 23 October 1981

NAVSEA Instruction

- 6240.1A: Environmental Quality Program, Policy and Responsibilities for. 23 December 1977

Naval Activity

Chapter 5: Water Pollution Abatement Ashore

Typical Elements for Compliance	Indian Head Budget Element	FY-83 Cost
NPDES permitted industrial sources	NPDES permitted industrial sources	
Administration/technical support	Administration/technical support	$ 4,400
Sampling	Sampling	16,000
Analysis	Analysis	8,700
Reporting	Reporting	35,000
NPDES permitted sewage plant	NPDES permitted sewage plant	
Operations	Operations	85,000
Maintenance	Maintenance	123,000
Supervision	Supervision	8,000
Training	Training	2,000
Sampling	Sampling	2,000
Analysis	Analysis	30,000
Total cost		$314,100

CHAPTER 5. WATER POLLUTION ABATEMENT ASHORE – DIRECTIVE CHAIN

Legislative Requirements

- Clean Water Act of 1977
- Rivers and Harbors Act of 1899
- Marine Protection, Research and Sanctuaries Act of 1972, Sect. 101 Ocean Dumping: 23 October 1972
- Safe Drinking Water Act: 16 December 1974
- Coastal Zone Management Act of 1972

Executive Requirements

- E.O. 11988: Floodplain Management: 24 May 1977
- E.O. 11990: Protection of Wetlands: 24 May 1977

Federal Regulations

- 33 CFR 153: Control of Pollution by Oil and Hazardous Substances, Discharge Removal, Coast Guard
- 33 CFR 209: Army Corps of Engineers Regulations on Navigable Waters
- 33 CFR 320-330: Army Corps of Engineers Permit Program Regulations
- 40 CFR 109: Criteria for State, Local, and Regional Oil Removal Contingency Plans
- 40 CFR 110: Discharge of Oil
- 40 CFR 112: Oil Prevention
- 40 CFR 113: Liability Limits for Small Onshore Oil Storage Facilities .
- 40 CFR 114: Interim Regulations on Civil Penalties for Violations of Oil Pollution Prevention
- 40 CFR 116: Designation of Hazardous Substances
- 40 CFR 117: Determination of Reportable Quantities for Hazardous Substances
- 40 CFR 122: National Pollutant Discharge Elimination System Permit Regulations
- 40 CFR 123: State NPDES Permit Program Requirements
- 40 CFR 125: Criteria and Standards for the National Pollutant Discharge Elimination System
- 40 CFR 133: Secondary Treatment Information
- 40 CFR 136: Test Procedures for the Analysis of Pollutants
- 40 CFR 220-225, 227-229: Ocean Dumping Regulations and Criteria
- 40 CFR 230: Discharge of Dredged or Fill Material into Navigable Waters
- 40 CFR 231: Disposal Site Determination Under the Water Act
- 40 CFR 403: Pretreatment Standards
- 40 CFR 129: Toxic Pollutant Effluent Standards
- 40 CFR 401: General Provisions for Effluent Guidelines and Standards
- 40 CFR 413: Effluent Guidelines and Standards for Electroplating
- 40 CFR 414: Effluent Guidelines and Standards for Plastics and Synthetics
- 40 CFR 416: Effluent Guidelines and Standards for Plastics and Synthetics
- 40 CFR 418: Effluent Guidelines and Standards for Fertilizer Manufacture
- 40 CFR 423: Effluent Guideline for Steam Electric Power Generating
- 40 CFR 459: Effluent Guidelines for Photographic Processing

DOD Requirements

- DOD Directive 4120.14: New Policies by E.O. 12088 and OMB Circular A-106, Implementation of; and Air and Water Pollution from DOD Facilities, Policies. 30 August 1977
- DOD Instruction 4170.6: Fish and Wildlife Management Program, Establishment: 21 June 1965
- DOD Instruction 4170.8: Soil and Water Management Program, Implementation: 8 November 1978
- DOD Directive 6050.4: Marine Sanitation Devices for Ships, Policy and Regulations: 23 October 1978
- DOD Directive 6230.1: Safe Drinking Water Act, Policy: 24 April 1978

Navy Requirements

- OPNAVINST 5090.1: Environmental and Natural Resources Protection Manual: 26 May 1983
- BUMEDINST 6240.3C: Standards for Potable Water: 25 August 1972
- NAVFACINST 4730.28: Treatment Devices, Commercial Procurement, Testing: 8 June 1977
- NAVFACINST 4862.5A: Industrial Wastewater Control Projects: 31 July 1980

Chapter 6: Air Pollution Abatement Ashore

Typical Elements for Compliance	Indian Head Budget Element	FY-83 Cost
Administration/technical support	Administration	$ 2,200
Operating expense		
Maintenance of installed equipment		
Ambient air monitoring	Air monitor	6,000
Stack monitoring	Stack monitor	17,000
	Monitor decontamination of burning ground (one-time cost)	2,000
Total cost		$27,200

CHAPTER 6. AIR POLLUTION ABATEMENT ASHORE – DIRECTIVE CHAIN

Legislative Requirements

- Clean Air Act
- National Energy Conservation Policy Act. Sect. 107, Statute Against Order of Local Fuel Source Usage: 9 November 1978
- Energy Supply and Environmental Coordination Act of 1974. Sect. 2, Coal Conversion and Allocation. Sect. 213, Fuel Economy Improvement from New Motor Vehicles: 24 June 1974

Executive Requirement

- E.O. 11602: Clean Air Act; Administration of Federal Contracts: 30 June 1971

Federal Regulations

- 40 CFR 50: National Primary and Secondary Ambient Air Quality Standards
- 40 CFR 51: Preparation of Implementation Plans, Subpart V – Maryland
- 40 CFR 55: Energy-Related Authority, Subpart V – Maryland (§ 55.450 Delayed Compliance Order – 46 FR53143; NOSIH Goddard Power Plant: 28 October 1981)
- 40 CFR 58: Ambient Air Quality Surveillance
- 40 CFR 60: Standards of Performance for New Stationary Sources
- 40 CFR 61: National Emission Standards for Hazardous Air Pollutants (Asbestos, Beryllium Rocket Motor Firings)
- 40 CFR 62: State Plans for Designated Facilities and Pollutants
- 40 CFR 65: Delayed Compliance Orders Under the Clean Air Act
- 40 CFR 66: Assessment and Collection of Non-Compliance Penalties
- 40 CFR 67: Federal Approval of State Non-Compliance Penalty Programs

DOD Requirement

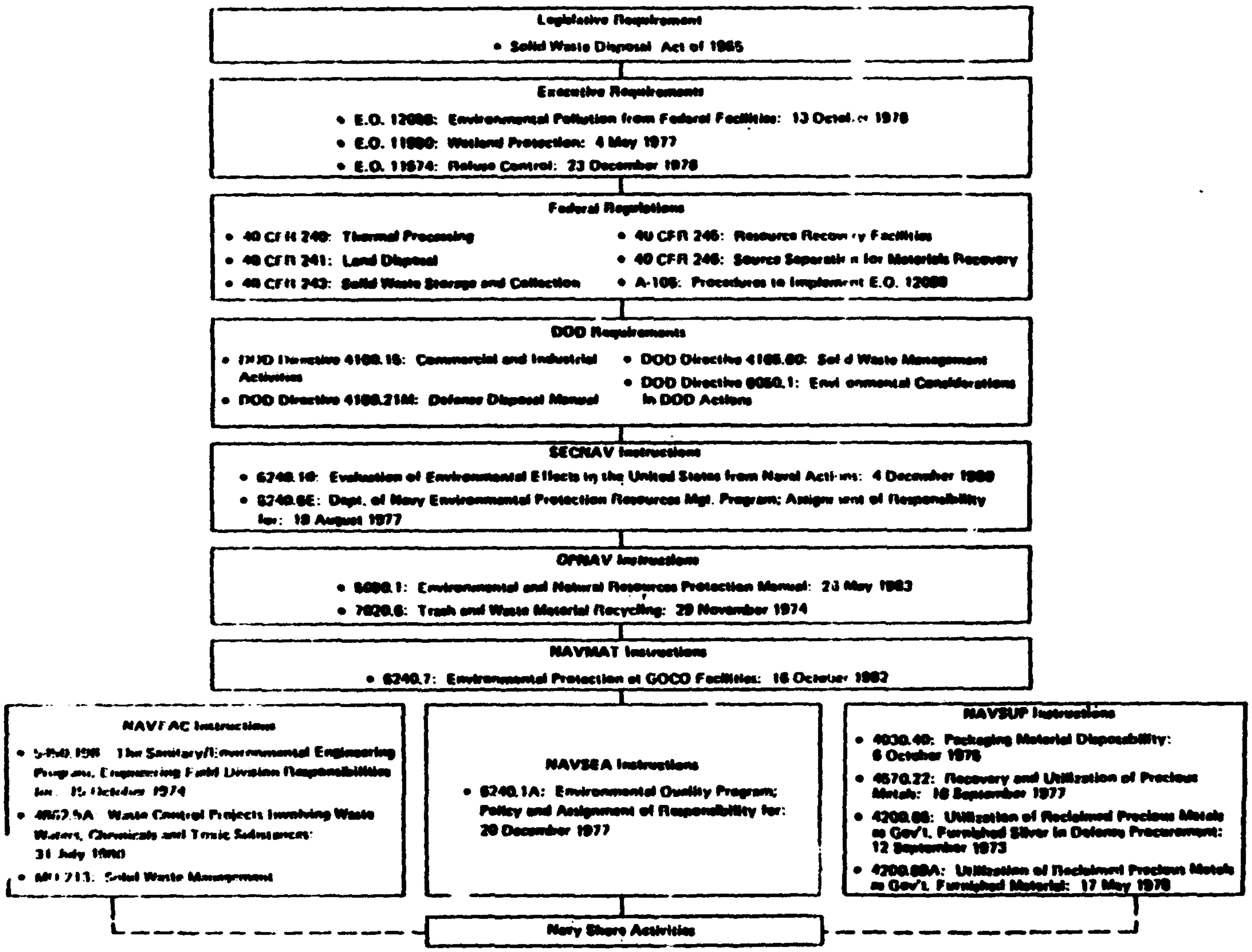
- DOD Instruction 4120.14: New Policies by E.O. 12088 and OMB Circular A-106, Implementation of; and Air and Water Pollution from DOD Facilities, Policies: 30 August 1977

Navy Requirement

- OPNAV 5090.1: Navy Environmental and Natural Resources Protection Manual: 26 May 1983

Typical Elements for Compliance	Indian Head Budget Element	FY-83 Cost
Administrative/technical support	Administrative/technical support	$ 33,591
Transportation	Transportation	157,000
Spill contingency planning		—
Spill prevention control and countermeasures plan (SPCC)		—
Incineration		—
Landfill operations	Landfill operations	19,000
Containerization		—
Separation and identification	Separation and identification	10,703
Training	Training	18,000
Manifesting and reporting		—
Permits	Permits	3,000
Storage	Storage of equipment, recycle, etc.	10,000
Recycling and reclamation	Recycling including precious metals	5,400
Total cost		$256,694

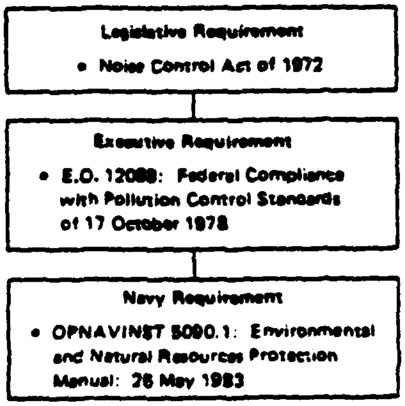
CHAPTER 7. SOLID WASTE MANAGEMENT AND RESOURCE RECOVERY ASHORE – DIRECTIVE CHAIN



Chapter 8: Noise Abatement Ashore

Typical Elements for Compliance	Indian Head Budget Element	FY-83 Cost
Monitoring		—
Sound barrier maintenance		—
Additional cost of operations (to reschedule etc.)		—
Total cost		$ 0

CHAPTER 8. NOISE ABATEMENT ASHORE – *DIRECTIVE CHAIN*



Chapter 9: Pesticide Pollution Abatement Ashore

Typical Elements for Compliance	Indian Head Budget Element	FY-83 Cost
	Contract	$30,000
Total cost		$30,000

CHAPTER 9. PESTICIDE POLLUTION ABATEMENT ASHORE – DIRECTIVE CHAIN

Legislative Requirements

- Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), as Amended
- Federal Environmental Pesticide Control Act of 1972: 21 October 1972
- Comprehensive Environmental Response, Compensation and Liability Act of 1980, as Amended

Executive Requirement

- E.O. 12088: Federal Compliance: 13 October 1978

Federal Regulations

- A-106: Procedures to Implement Executive Order 12088: 31 December 1974
- 40 CFR 300: *National Oil and Hazardous Substances Pollution Contingency Plan*

DOD Requirements

- DOD Directive 4120.14: Environmental Pollution Prevention, Control and Abatement: 30 August 1977
- DOD Directive 4150.7: Department of Defense Pest Management Program: 6 November 1978
- DOD Directive 5154.12: Armed Forces Pest Management Program: 23 July 1979

Navy Requirement

- OPNAVINST 5090.1: Environmental and Natural Resources Protection Manual: 26 May 1983

NAVSEA Instruction

- 6240.1A: Environmental Quality Program; Policy and Assignment of Responsibility for 20 September 1977

Chapter 10: Oil Pollution Abatement Ashore

Typical Elements for Compliance	Indian Head Budget Element	FY-83 Cost
Oil spill control plan	Review of oil spill control plan	$ 1,000
Maintenance of oil handling and storage facilities	Maintenance of oil off-loading and storage facilities (1.6 million gal at 114 locations)	25,000
	Intra-station transportation of used and waste oil	2,000
	DPDO support of waste oil	500
Total cost		$28,500

CHAPTER 10. OIL POLLUTION ABATEMENT ASHORE – DIRECTIVE CHAIN

Legislative Requirements

- Federal Water Pollution Control Act, as Amended
- The Oil Pollution Act, as Amended
- National Environmental Policy Act of 1969
- Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as Amended

Executive Requirement

- E.O. 11990: Wetland Protection: 24 May 1977
- E.O. 12088: Federal Compliance: 13 October 1978

Federal Regulations

- A-106: Procedures to Implement Executive Order 12088: 31 December 1974
- 40 CFR 109: Criteria for State, Local and Regional Oil Removal Contingency Plans
- 40 CFR 110: Discharge of Oil
- 40 CFR 112: *Oil Pollution Prevention*
- 40 CFR 113: Liability Limits for Small Onshore Oil Storage Facilities
- 40 CFR 114: Civil Penalties for Violation of Oil Pollution Prevention Regulations
- 40 CFR 300: National Oil and Hazardous Substances Pollution Contingency Plan

DOD Requirements

- DOD 4120.14: Environmental Pollution Prevention, Control and Abatement: 30 August 1977
- DOD 5030.41: National Oil and Hazardous Substances Contingency Plan: 1 June 1977
- *DOD 6050.1: Environmental Considerations in DOD Actions: 30 July 1979*

Navy Requirements

- OPNAVINST 5090.1: Environmental and Natural Resources Protection Manual: 26 May 1983
- NAVMATINST 4731.1A: Oil, Policies and Responsibilities for Program, 27 January 1981

NAVSUP Instruction

- 6240.2B: Pollution Prevention, Control at Bulk Facilities 14 December 1982

NAVFAC Instructions

- 6240.2A: Oil Spill Equipment Procurement Program 22 October 1981
- 10340.7B: Waste Oil Management Program 17 August 1978

NAVSEA Instruction

- 6240.1A: Environmental Quality Program; Policy and Responsibility for: 20 December 1977

Chapter 11: Hazardous Materials Environmental Management Ashore

Typical Elements for Compliance	Indian Head Budget Element	FY-83 Cost
	Part 1: HM/HW Management	
Designate point of contact	Administration and technical support	$ 48,000
HM survey		
Develop HM management plan		
Annual reporting (federal and state)		
Disposal of HM/HW	HW Disposal (contract)	25,000
Manifesting	HW Manifesting	2,200
Storage	HW Storage	1,100
Training	HW Training	8,000
Equipment	HW Equipment	0
	HW Incineration	135,800
	HW Permits	2,700
Subtotal cost (Part 1)		$222,800
	Part 2: Inactive HS Disposal Sites	
NACIP support	HW Administration/technical support	2,100
Subtotal cost (Part 2)		$. 2,100
	Part 3: Polychlorinated Biphenyls (PCBs)	
PCB Transportation	PCB Transportation	600
PCB Administration/Technical Support	PCB Administration/technical support	2,040
PCB manifesting	PCB Manifesting	840
PCB storage	PCB Storage	500
Subtotal cost (Part 3)		$ 3,980
Total cost (Parts 1, 2 & 3)		$228,880

CHAPTER 11. HAZARDOUS MATERIALS ENVIRONMENTAL MANAGEMENT ASHORE – DIRECTIVE CHAIN

Part 1. Hazardous Materials/Hazardous Waste Management

Legislative Requirement

- Resource Conservation and Recovery Act 1976

Executive Requirements

- E.O. 12088: Environmental Pollution from Federal Facilities: 13 October 1978
- E.O. 11990: Wetland Protection: 4 May 1977
- E.O. 11574: Refuse Control: 23 December 1970

Federal Regulations

- 40 CFR 260: Definitions
- 40 CFR 261: Identification and Listing
- 40 CFR 262: Standards for Generators
- 40 CFR 263: Standards for Transporters
- 40 CFR 264: Standards for T/S/D Facilities
- 40 CFR 265: Interim Status Standards for T/S/D Facilities
- 40 CFR 122 and 124: Permits for T/S/D Facilities
- 40 CFR 123: Guidelines for Authorized State Programs
- A-106: Procedures to Implement E.O. 12088

DOD Requirements

- DOD Directive 4100.15: Commercial and Industrial Activities
- DOD Directive 4160.21M: Defense Disposal Manual
- DOD Directive 4165.60: Solid Waste Management
- DOD Directive 6050.1: Environmental Considerations in DOD Actions

SECNAV Instructions

- 6240.10: Evaluation of Environmental Effects in the United States from Naval Actions: 4 December 1980
- 6240.6E: Dept. of Navy Environmental Protection Resources Mgmt. Program; Assignment of Responsibility for: 18 August 1977

OPNAV Instructions

- 5090.1: Environmental and Natural Resources Protection Manual: 26 May 1983
- 7020.6: Trash and Waste Material Recycling: 29 November 1974

NAVMAT Instructions

- 6240.7: Environmental Protection at GOCO Facilities: 16 November 1982
- 6240.6A: Hazardous Materials Environmental Mgmt. Program; Navy: 8 May 1982

NAVFAC Instructions

- 5450.19B: The Sanitary/Environmental Engineering Program; Engineering Field Division, Responsibilities for: 15 October 1974
- 4862.5A: Waste Control Projects Involving Wastewaters; Chemicals and Toxic Substances: 31 July 1980
- MO-213: Solid Waste Management

NAVSEA Instruction

- 6240.1A: Environmental Quality Program; Policy and Responsibility for: 20 December 1977

Navy Shore Activities

Part 2. Inactive Hazardous Substances Disposal Sites

Legislative Requirements

- Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)

OPNAV Instruction

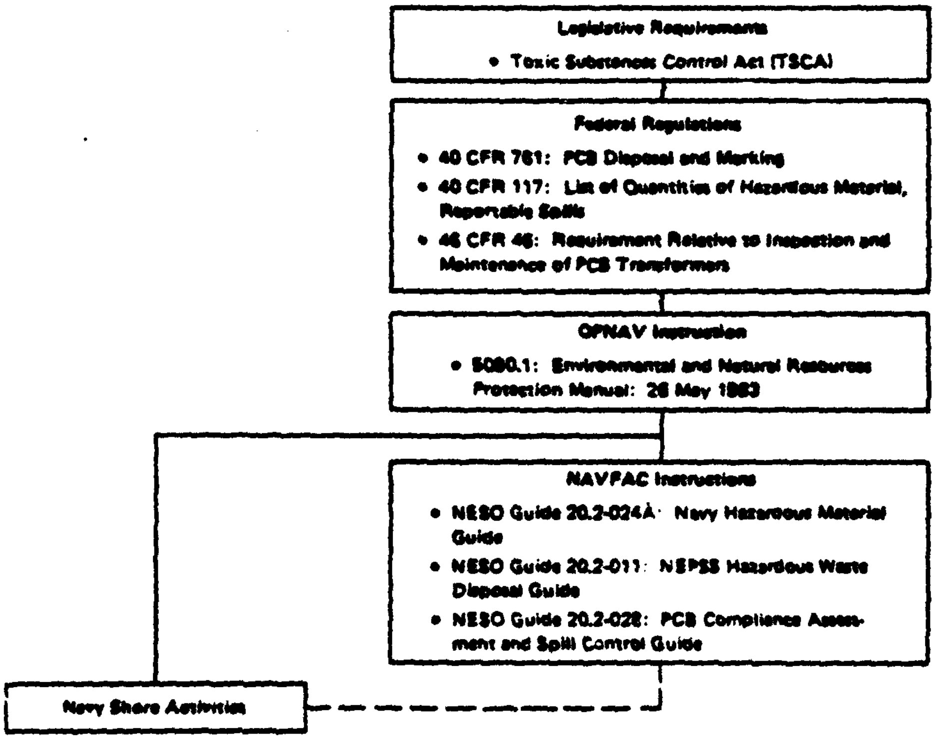
- 5090.1: Environmental and Natural Resources Protection Manual: 26 May 1983

NAVFAC Instruction

- NEESA 20.2-035A: NACIP Guide for Conducting an Initial Assessment Study

Navy Shore Activities

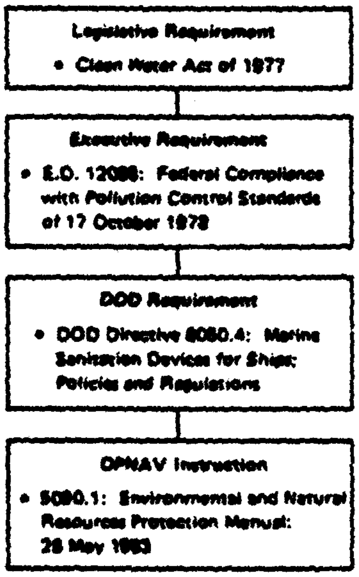
Part 3. Polychlorinated Biphenyls (PCBs)



Chapter 12: Pollution Abatement Afloat

Typical Elements for Compliance	Indian Head Budget Element	FY-83 Cost
Sewage, pulped garbage, pulped trash, and wastewater		—
Foreign source food and garbage		—
Domestic garbage		—
Trash or solid waste		—
Oils and oily waste		—
Hazardous substances turned into stores		—
Hazardous waste		—
Spill cleanup, planning, and operations		—
Total cost		$0

CHAPTER 12. POLLUTION ABATEMENT AFLOAT – DIRECTIVE CHAIN



Chapter 13: Oil and Hazardous Substance Release Contingency Planning

Typical Elements for Compliance	Indian Head Budget Element	FY-83 Cost
Part 1: Navy Organizational Aspects for Removal of Oil and Hazardous Substances		
Part 1 Discusses area-wide planning. There are no local costs in this part except for support provided to an area wide plan.		\$0
Part 2: Navy Oil Discharge Response		
Develop oil spill contingency plan	Administration/technical support	—[1]
Develop spill prevention control and countermeasures plan (SPCC)		—[1]
Develop reporting procedures	Reporting	—[1]
Designate personnel for response		—[1]
Designate equipment for response	Equipment	—[1]
Train designated personnel	Training	—[1]
Oil spill clean-up operations	Spill cleanup	—[1]
Subtotal cost (Part 2)		—[1]
Part 3: Navy HS Release Response		
Develop HS spill contingency plan	Administration/technical support	45,700
Develop spill prevention control and countermeasures plan (SPCC)		
Develop reporting procedures	Reporting	3.500
Designate personnel for response		
Designate equipment for response	Equipment	10,000
Train designated personnel	Training	5.500
HS spill clean-up operations	Spill cleanup	25.000
Subtotal cost (Part 3)		\$89.700
Part 4: Salvage-Related Oil and HS Spills		\$0
This Section applies to Navy participation in the salvage of private and navy vessels. This section does not apply to the normal operations of shore activities.		
Total cost		\$89.700

[1] The costs listed for Part 3 are actually the total costs for the corresponding elements for both Parts 2 and 3

CHAPTER 13. OIL AND HAZARDOUS SUBSTANCE RELEASED CONTINGENCY PLANNING – DIRECTIVE CHAIN

Legislative Requirements

- Federal Water Pollution Control Act, as Amended
- Oil Pollution Act of 1961, as Amended
- Resource Conservation and Recovery Act of 1976
- Comprehensive Environmental Response and Liability Act of 1980
- National Environmental Policy Act of 1969

Executive Requirements

- E.O. 12316: Responses to Environmental Damage: 14 August 1981
- E.O. 12088: Federal Compliance: 13 October 1978
- E.O. 11990: Wetland Protection: 24 May 1977

Federal Requirements

- 40 CFR 109: Criteria for State, Local, and Regional Oil Removal Contingency Plans
- 40 CFR 110: Discharge of Oil
- 40 CFR 112: Oil Pollution Prevention
- 40 CFR 113: Liability Limits for Small Onshore Oil Storage Facilities
- 40 CFR 114: Civil Penalties for Violation of Oil Pollution Prevention Regulations
- 40 CFR 117: Reportable Quantities for Hazardous Substances
- 40 CFR 260–265: Regulations for the Management of Hazardous Wastes
- 40 CFR 300: National Oil and Hazardous Substances Pollution Contingency Plan
- A-106: Procedures to Implement E.O. 12088: 31 December 1974

DOD Requirement

- DOD Directive 4120.14: Implementation of E.O. 12088 and A-106
- DOD Directive 5030.41: National Oil and Hazardous Substances Contingency Plan
- DOD Directive 6050.1: Environmental Considerations in DOD Actions

SECNAV Instructions

- 6240.10: Evaluations of Environmental Effects in the United States from Naval Actions: 4 December 1980

OPNAV Instructions

- 5090.1: Environmental and Natural Resources Protection Manual: 26 May 1983
- 3100.6C: Special Incident Reporting: 15 July 1977

NAVMAT Instructions

- 4731.1A: Oil, Policies and Responsibilities for Program: 27 January 1981
- 6240.6A: Navy Hazardous Materials Environmental Management Program: 5 June 1982
- 6240.7: Environmental Protection at GOCO Facilities: 16 November 1982

NAVSUP Instruction

- 6240.25: Pollution Prevention, Control at Bulk Fuel Facilities: 14 December 1982

NAVFAC Instructions

- 6240.2A: Oil Spill Equipment Procurement Program
- 10340.7B: Waste Oil Management Program: 17 August 1978

NAVSEA Instruction

- 6240.1A: Environmental Quality Program; Policy and Responsibility for: 20 December 1977

Navy Shore Activities

Chapter 14: Ocean Dumping

In general, regulations prohibit transporting material from shore for ocean dumping. Some exceptions are allowed and permits are issued on a case-by-case basis. Weapons and Combat Systems Directorate field activities do not have any known permits for ocean dumping even though there is occasional ocean dumping of dredged material. This chapter includes burial at sea (see also 40 CFR 229.1 and BUMEDINST 5360.1D of 4 October 1982).

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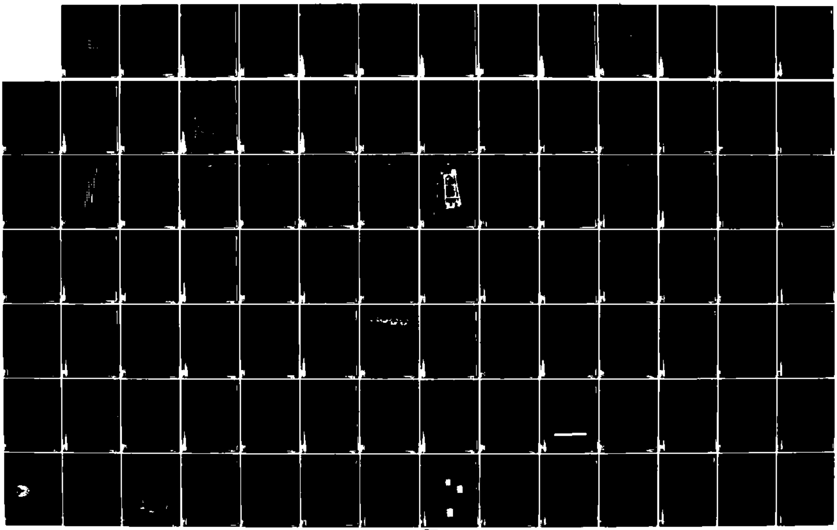

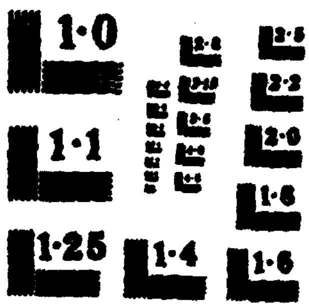
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CHAPTER 14. OCEAN DUMPING – DIRECTIVE CHAIN

Legislative Requirement

- Marine Protection, Research and Sanctuaries Act of 1972

Executive Requirement

- E.O. 12088: Federal Compliance with Pollution Control Standards

Federal Regulation

- 40 CFR 221-227

OPNAV Instruction

- 5090.1: *Environmental and Natural Resources Protection Manual*: 26 May 1983

Chapter 15: Natural. Cultural, and Historic Resources

Typical Elements for Compliance	Indian Head Budget Element	FY-83 Cost
Soil and water conservation		
Administration and planning	Administration and planning	$ 1,800
Landscape (minor construction)	Landscaping	12,000
Training		—
Subtotal		$13,800
Forest Management		
Reforestation	Reforestation	2,500
Timberstand improvement	Timberstand improvement	15,000
Fire protection	Fire protection	666
Timber area access roads	Timber area access roads	—
Timber management	Timber management	25,000
Training		
Subtotal		$43,166
Fish and wildlife		
Planning and management	Planning and management	
Inventory and survey	Inventory and survey	3,600
Feral animal control	Population control	3,000
Pest control	Pest control	2,880
Habitat improvement		3.000
Hunting management	Game warden	—
Training	Training	—
Subtotal		$12.480
Outdoor recreation		
Planning		—
Minor construction		—
Maintenance		—
Training		—
Subtotal		$ 0
Natural and cultural resources		
Planning		—
Minor construction		—
Maintenance		—
Training		—
Subtotal		$ 0
Total cost		$69.446

CHAPTER 15. NATURAL, CULTURAL. AND HISTORIC RESOURCES – DIRECTIVE CHAIN

Legislative Requirements

- P.L. 85-624: Fish and Wildlife Coordination Act
- P.L. 86-797: Fish and Wildlife Conservation on Military Reservations
- P.L. 89-29: National Historical Preservation Act
- P.L. 89-669: Fish and Wildlife Conservation Act
- P.L. 90-465: Conservation Programs on Military Reservations
- P.L. 90-583: Noxious Plant Control
- P.L. 91-190: National Environmental Policy Act of 1969 (NEPA)
- P.L. 92-522: Marine Mammal Protection Act of 1972
- P.L. 92-532: Marine Protection, Research and Sanctuaries Act of 1972
- P.L. 92-583: Coastal Zone Management Act
- P.L. 93-205: Endangered Species Act of 1973
- P.L. 93-408: Youth Conservation Corps Act of 1972 Amended
- P.L. 93-452: Conservation and Rehabilitation Program on Military and Public Lands
- P.L. 93-629: Federal Noxious Weed Act of 1974
- P.L. 95-524: Comprehensive Employment and Training Act Amendments – 1978
- P.L. 95-632: Endangered Species Act of 1973 (1978 Amendments)
- H.R. 6602: National Heritage Policy Act of 1979
- Title 10 USC 2667: Leases: Non-excess Property
- Title 10 USC 2671: Military Reservations and Facilities; Hunting, Fishing, and Trapping
- Title 16 USC 590: Soil Conservation
- American Indian Religious Freedom Act
- 16 USC 1271: National Trails System Act of 1968
- 16 USC 1274: Wild and Scenic River Act

Executive Requirements

- E.O. 11514: Protection and Enhancement of Environmental Quality
- E.O. 11593: Protection and Enhancement of the Cultural Environment
- E.O. 11643: Environmental Safeguards on Activities for Animal Damage Control on Federal Lands
- E.O. 11988: Floodplain Management
- E.O. 11989: Off-Road Vehicles on Public Lands
- E.O. 11990: Protection of Wetlands
- E.O. 11991: Protection and Enhancement of Environmental Quality

DOD Requirements

- DOD Directive 4700.1: Natural Resources Conservation and Management
- DOD Instruction 5300.13: Natural Resources – The Secretary of Defense Conservation Award
- DOD Directive 6050.2: Use of Off-Road Vehicles on DOD Lands, as Amended
- DOD Instruction 7310.8: Accounting for Production and Sale of Lumber and Timber Products

Chapter 16: Industrial and Drinking Water Systems

Typical Elements for Compliance	Indian Head Budget Element	FY-83 Cost
Supervision	Supervision	22,000
Training	Training	1,000
Operations	Operations	201,000
Maintenance	Maintenance	253,000
Sampling	Sampling	1,000
Analysis	Analysis	10,000
Total cost		$488,000

CHAPTER 16. INDUSTRIAL AND DRINKING WATER SYSTEMS – DIRECTIVE CHAIN

Legislative Requirement

- Clean Water Act of 1977

Federal Regulations

- 40 CFR 141: National Interim Primary Drinking Water Regulation
- 40 CFR 142: National Interim Primary Drinking Water Regulation Implementation
- 40 CFR 143: National Secondary Drinking Water Regulation
- 40 CFR 144: Permit Regulations for the Underground Injection Control Program
- 40 CFR 149: Review of Projects Affecting Sole Source Aquifers

OPNAV Instruction

- 5090.1: Environmental and Natural Resources Protection Manual: 26 May 1983

Chapter 17: Secretary of the Navy Environmental Protection Annual Awards Program

The Secretary of the Navy provides recognition and awards for activity environmental and natural resources protection programs. These awards are not a cost against the local activity.

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REMEDIAL ACTION OF HAZARDOUS WASTE
U.S. ARMY CORPS OF ENGINEERS
ANNISTON, ALABAMA

Presented By:

Larry G. Copeland, P.E.
Roy F. Weston, Inc.
4329 Memorial Drive, Suite C
Decatur, Georgia 30032
(404) 294-7575

and

Dr. Robert J. York
U.S. Army Toxic & Hazardous Materials Agency
Aberdeen Proving Ground, Maryland 21010
(301) 671-2270

INTRODUCTION

Anniston Army Depot (ANAD) is located in northeastern Alabama in Calhoun County. The Depot is located approximately ten miles west of Anniston, Alabama, and sixty miles east of Birmingham, Alabama.

Anniston Army Depot (ANAD)

One of the primary missions of the Depot is the repair of combat vehicles. Industrial processes which are utilized in the accomplishment of this mission led to the production of a large number of waste chemicals, mainly degreasing, paint stripping and metals processing sludges. Many of these waste chemicals are classified as hazardous under both Federal and State of Alabama hazardous waste regulations.

Beginning in 1971-1972 and continuing until 30 September 1981, containerized sludge wastes were buried in seven trenches located in an elevated area with approximately 30 feet of relief northwest of the Depot industrial area. The sludge disposal trench site occupied approximately two acres near the existing Depot sanitary landfill (Figure 1). At initiation of the project, six of the trenches had been completely covered and the seventh remained partially open.

An additional site, the old lagoon sludge pile, consisted of materials removed from the bottom of a lagoon which was closed in the early 1960's. This pile was covered with a synthetic liner and covered with earth.

Organic contaminants, including volatile aromatics, phenols and phthalate esters, were indicated. The most significant groundwater contaminants were trichloroethene and methylene chloride. In spring 1981, further sampling and GC/MS analyses of twelve wells were conducted for volatile organics. At that time other organic contaminants, in addition to the confirmed trichloroethene and methylene chloride, were detected.

The potential for localized groundwater contamination led to the decision to exhume, remove and dispose of the contaminated material in the seven disposal trenches. As part of this contract, the hazardous sludges in the old lagoon sludge pile were to be removed, although groundwater contamination was not associated with this site.

Through the use of ground penetrating radar (GPR), magnetometry, metal detection and electromagnetics, the exact boundaries of the chemical sludge disposal trenches were determined. Estimates of the depth of the trenches were made from GPR data. Trenches 1 to 6 were estimated at 12 feet deep; trench 7 was estimated at approximately 17 feet deep. The corners of each trench were surveyed (State Planar Coordinate System) for the exact locations for removal operations. Cont'd

A geotechnical evaluation of the area containing the disposal sites was conducted by a previous contractor during spring and summer 1981 to establish the following:

- Delineation of the actual chemical sludge disposal trench boundaries

- Determination of the bedrock depth and configuration

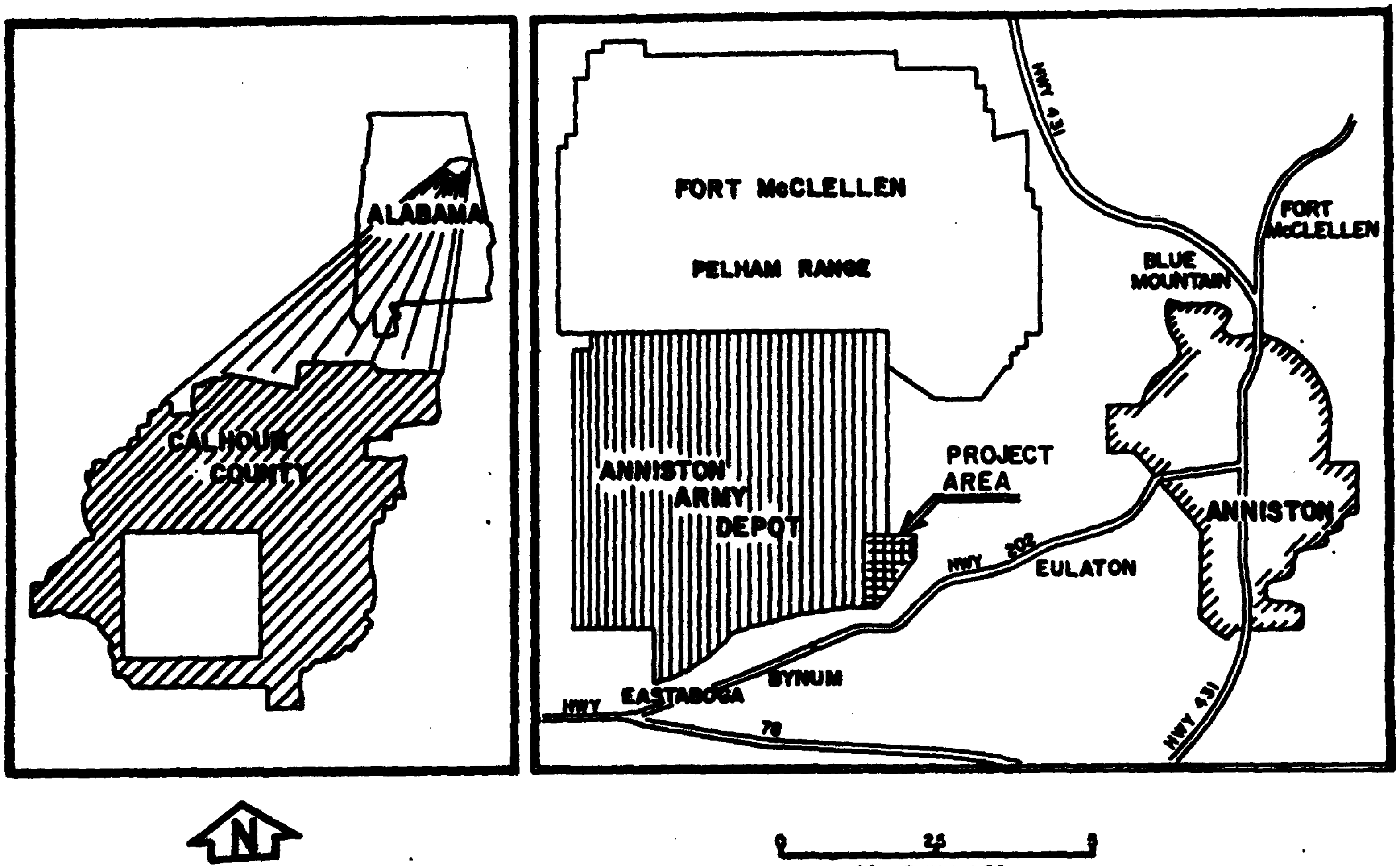


FIGURE 1
GENERAL LOCATION MAP

- Direction(s) of shallow groundwater flow
- Evaluation of the potential for contaminant migration into bedrock

Following procurement and contract negotiation by the U.S. Army Corps of Engineers (COE), Huntsville Division, the responsibility of administering the contract for remedial action at the Anniston Army Depot was assigned to the Mobile District, COE. Responsibility for administering the technical execution of the project to remove and dispose of hazardous waste materials from ANAD was maintained by the U. S. Army Toxic and Hazardous Materials Agency (USATHAMA).

The quantity of material to be removed from the trenches and the old lagoon site was initially estimated at 54,675 tons. Up to 50,000 additional tons were authorized for removal under the contract if more extensive excavation was required to achieve effective removal of the contaminated soil. Specific exhumation criteria stated removal of soil two feet below the trench bottoms and five feet horizontally from the trench sides, plus removal of all soil partitions between trenches. If visual evidence of contamination remained, additional exhumation was performed at the direction of the Contracting Officer's Representative.

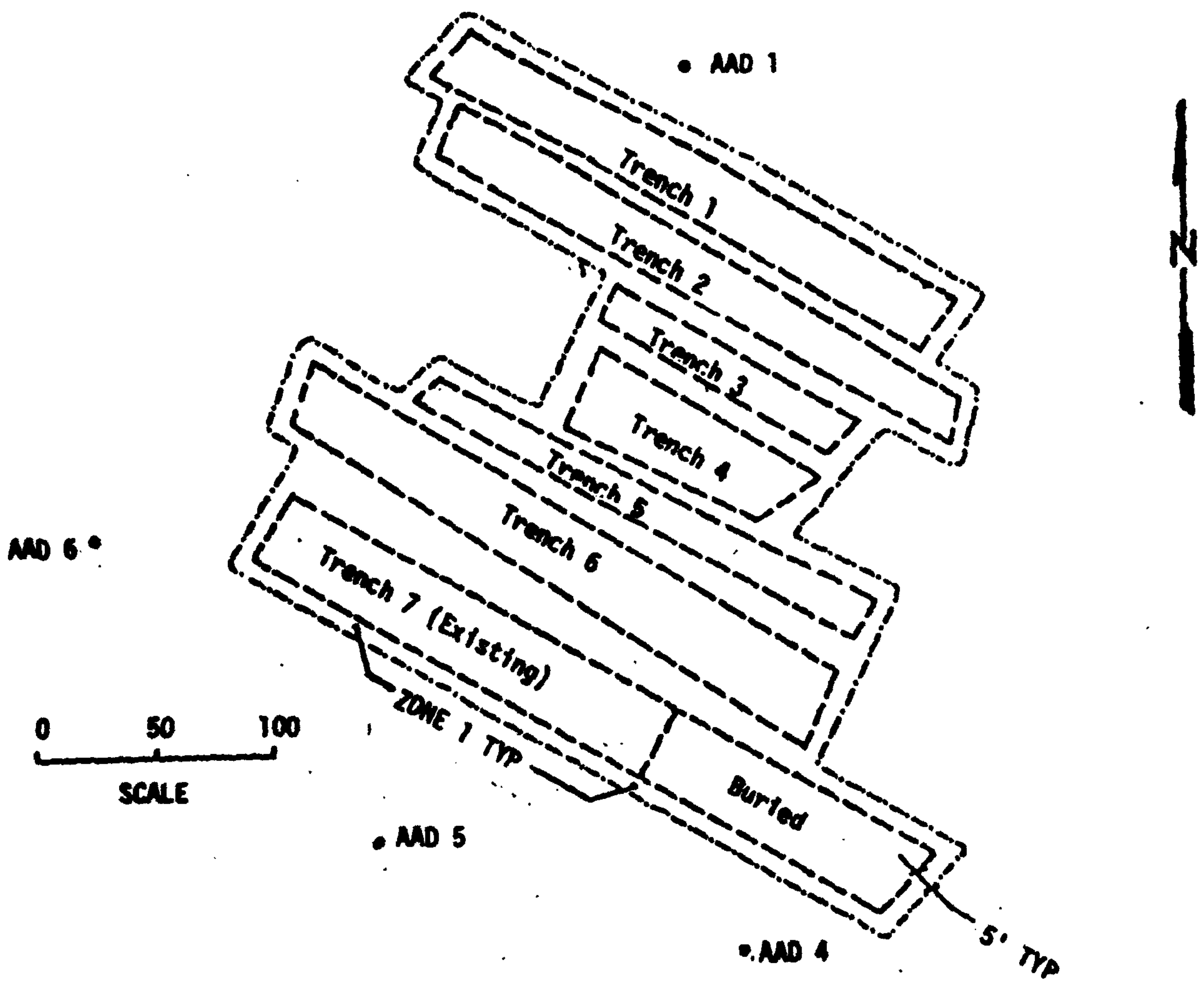
A total of 62,119 tons of contaminated material and soils from the chemical sludge disposal trenches, old lagoon sludge pile and chemical sump at Building 130 were exhumed, transported and disposed of during the project. Hazardous materials were transported by Magic City Trucking of Birmingham, Alabama, and Chemical Waste Management, Inc., of Emelle, Alabama, permitted hazardous waste carriers, in accordance with applicable State and Federal regulations to Chemical Waste Management, Inc., a RCRA-permitted hazardous waste disposal facility at Emelle, Alabama.

HAZARDOUS WASTE REMOVAL OPERATIONS

Primary waste removal operations at ANAD consisted of handling and disposing of materials from two separate sites: the chemical sludge trenches and the old lagoon site. These sites were located approximately one mile from each other and were arbitrarily labelled by a previous contractor as Site Z-1 (chemical sludge trenches) and Site Z-2 (old lagoon sludge pile). The discussion of the sites follows the chronological order of their excavation. Figures 2 and 3 represent the operational layout of Sites Z-1 and Z-2, respectively.

During the latter phases of the removal operations, a small volume of waste material from the chemical sump at Building 130 was transferred to the trench site by ANAD personnel and was subsequently transported to the disposal site in Emelle, Alabama, by the permitted transporter.

Removal operations at ANAD were initiated with the excavation of Site Z-2, the old lagoon sludge pile. Site Z-2 consisted of waste sludge material that had been mounded up and covered with a thin plastic membrane. The site was located near the sanitary wastewater treatment plant and the spare parts "junkyard" for some of the vehicles repaired on the Depot.



LOCATION MAP OF BURIED
CHEMICAL SLUDGE TRENCHES
FIGURE 2

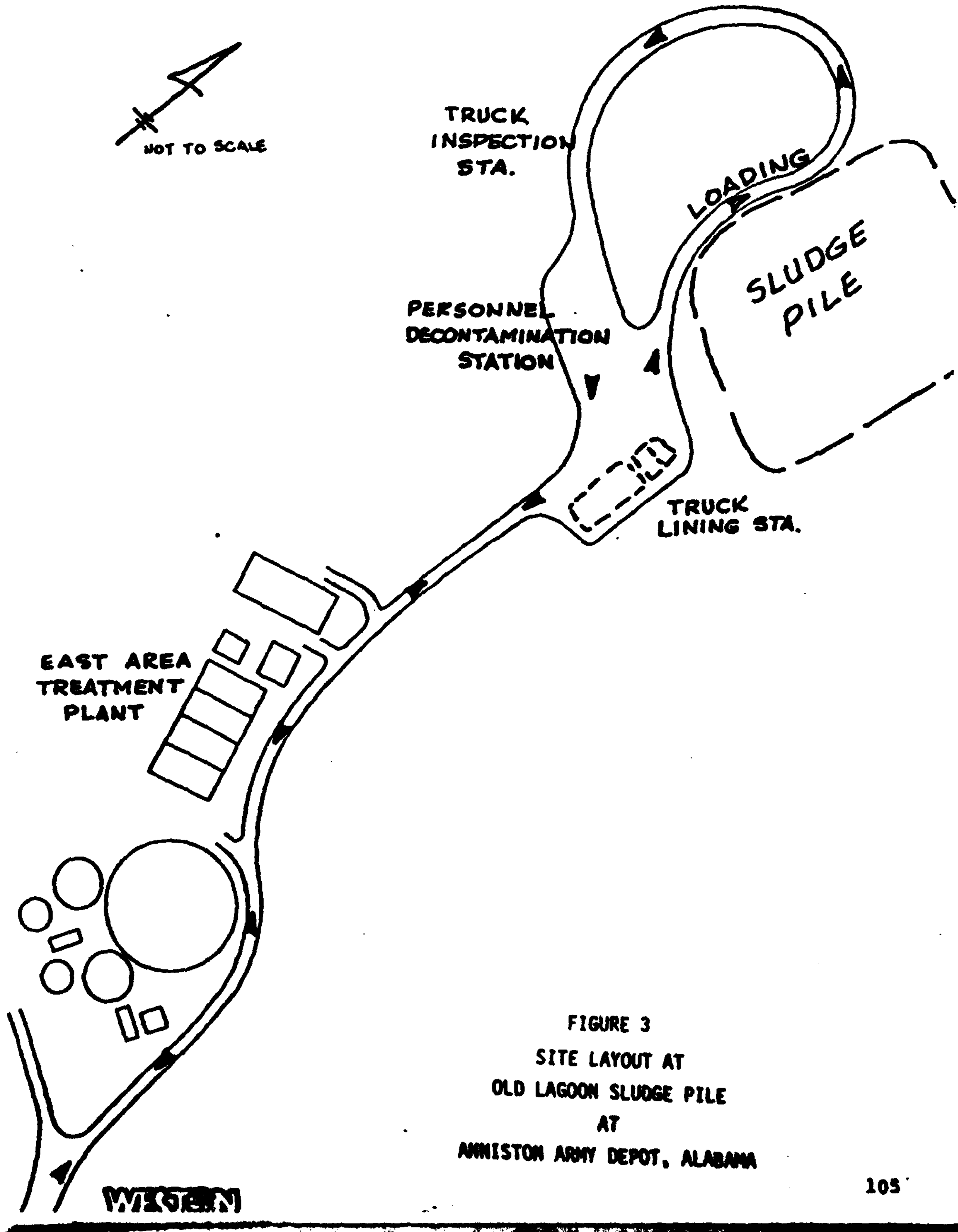


FIGURE 3

SITE LAYOUT AT

OLD LAGOON SLUDGE PILE

AT

ANNISTON ARMY DEPOT, ALABAMA

WESTERN

Site preparation at Z-2 involved building a gravel road to the site which could be used for access, truck preparation and loading. The road entered the area beside the sanitary treatment plant and continued into an elongated loop at the waste pile. The road was made of coarse gravel (several different grades) which allowed easy drainage and high durability.

Prior to the excavation efforts, the entire waste pile and associated work zones were ringed with a warning banner mounted on wooden laths to restrict any unauthorized entrance into the area. This barrier was sufficient since Z-2 was located in a rather remote area with low traffic, and Depot personnel had been briefed as to the operations at the waste pile. The warning banner was maintained throughout the duration of the excavation operations.

A decontamination area was established at the site. An on-site supply trailer housed equipment and tools, such as shovels, carpentry tools, eye wash and shower, spare safety equipment, gloves, and protective coveralls. The trailer was parked on the far side of the loop away from the waste pile. Visqueen which was be used to line the inside of the dump truck bodies was held on a rack at the rear of the trailer. This rack was designed for ease of operation in unrolling and cutting the appropriate length of liner to fit each truck.

Excavation at Site Z-2 began on November 16, 1982. The waste pile consisted of solid materials from a dewatered industrial waste holding lagoon which had contained various heavy metals and organic solvents used for electroplating and degreasing operations. A Caterpillar 977 tracked front-end loader was used to remove the cover and waste material and load it into the waiting semi-dump trucks.

The disposal operations at Site Z-2 proceeded slowly during the initial stages due to difficulty in estimating the weights of the loaded trucks prior to their leaving Site Z-2 to be weighed. After several days, however, the operators of the front-end loader were able to estimate the quantity of material to comprise the correct load limits and the number of trucks processed each day steadily rose.

Waste excavation and removal operations continued at the site through the beginning of January 1983. During this period a number of days were lost when the site was closed due to inclement weather conditions. Harsh weather also made it necessary to place a berm around the excavation areas to contain any runoff from the potentially contaminated soils. In an effort to minimize the effects of the rain and runoff, the open face of the excavation was covered at the end of each day's operation with a visqueen liner which was sandbagged around the edges to secure it in place.

As a result of the preventive measures taken at the loading area, decontamination of the transport vehicles was minimized. The heavy equipment used to excavate the site was moved to Site Z-1 where it was either used immediately on the site or decontaminated at the washdown facility prior to movement off the Depot. Site personnel underwent decontamination each time they exited from a contaminated work zone. The decontamination consisted of a washdown and rinse in a series of water-based, inorganic "stripping" compounds. Two decon solutions were utilized: the first, a solution containing 5 percent sodium carbonate (Na_2CO_3) and 5 percent trisodium phosphate (Na_2PO_4); the second, a solution containing 10 percent trisodium phosphate (Na_3PO_4). Coveralls worn by the site workers were disposed of daily to prevent any spread of contamination.

Spent wash water and decontamination solutions were piped to the decontamination pit from which liquid overflow was transferred to the holding basin of Site Z-1. Analyses of the liquids in the holding basin were conducted to ensure that levels of contamination did not exceed parameters specified in the State Indirect Discharge Permit issued to Weston for this project. Contents of the holding basin were transported by vacuum truck to the East Area Wastewater Treatment Plant at Anniston Army Depot for discharge in accordance with the permit. Sludges which collected in the decontamination pit were combined with sludges from the trenches for disposal at the RCRA-permitted hazardous waste facility.

Site Z-1 was significantly more complex than Site Z-2. Site Z-1 consisted of seven trenches located within an area measuring approximately 350' x 400'. These trenches contained buried drummed waste sludges from operations employing organic solvents. The Z-1 site was located in a saddle between two adjacent hills overlooking the Depot from the northeast.

Site preparation at Site Z-1 involved the following steps:

1. A gravel site access road was built to accommodate the truck traffic. This road extended around the site and bounded the inside of Trench 7 (the furthest from the command area and the first trench to be excavated).

2. A berm approximately two feet high was constructed around the periphery of the entire site to contain any contaminated runoff from the site.

3. A drum staging zone consisting of a berm and sectional areas was built to accommodate any intact drums which required sampling and special disposal.

4. A holding basin capable of containing over 100,000 gallons of liquid was built to serve as a repository for all decontamination wash waters, contaminated runoff and laboratory wash water.

5. Erosion control measures such as hay bales, swales and berms were constructed and placed to direct rain water and runoff away from the site in a controlled manner.

6. An automatic scale for weighing the trucks was installed in concrete beds in the command area.

7. All on-site wiring, plumbing, and carpentry was completed to allow the semi-permanent installation of a laboratory trailer, a supply trailer, a decontamination trailer, a command trailer, and a decontamination washdown pad.

Excavation of the buried wastes and the contaminated soil partitions between the trenches was accomplished using a Caterpillar 245 backhoe. The excavation was initiated at Trench 7 and proceeded sequentially across the site to Trench 1.

As the excavation progressed, the access road was reestablished using fresh gravel. Figure 4 depicts the truck routing at Size Z-1. The same general operating sequence used at Site Z-2 was used at Site Z-1 and proceeded as follows:

1. Trucks were staged in cleared fields several hundred yards from the site. Safety chains were attached and tightened, tarps were placed in their cradles, and the trucks were given a safety inspection by the driver.

2. Using CB radios, the drivers were instructed to proceed to the truck preparation area. Two technicians and the visqueen liner rack were stationed on a scaffold. The scaffold eliminated unnecessary climbing on the trucks and expedited truck preparation. The trucks were positioned beside the scaffold and the technicians lined and fastened the visqueen to the inside of the dump body.

3. The truck proceeded to the loading zone. Each truck was positioned to permit loading by the backhoe from the rear. Due to the backhoe's increased accuracy in placing material, deflector boards were not necessary to protect the truck wheels from contamination. On the few occasions when very wet material was encountered during the excavation, the tires were covered with visqueen to prevent spillage from the bucket contacting the wheels.

4. Subsequent to loading, the trucks proceeded to the tarping area. The technicians at the tarping zone were located on scaffolds which greatly increased their productivity and significantly reduced worker fatigue and the hazard of falling off the trucks.

5. After the trucks were tarped, they were weighed at the scale and either returned to the loading zone for more material (or for the removal of material) or were released to proceed to the disposal site at Emelle, Alabama.

SAFETY AND AIR MONITORING PROGRAM

An extensive safety program was designed for the AMAD project. The program was detailed in the Project Safety Plan which was approved by the Contracting Officer and subsequently implemented for the duration of the site activities at AMAD. The program included personnel training, use of protective clothing, a respiratory protection program, an exposure monitoring program, and medical surveillance.

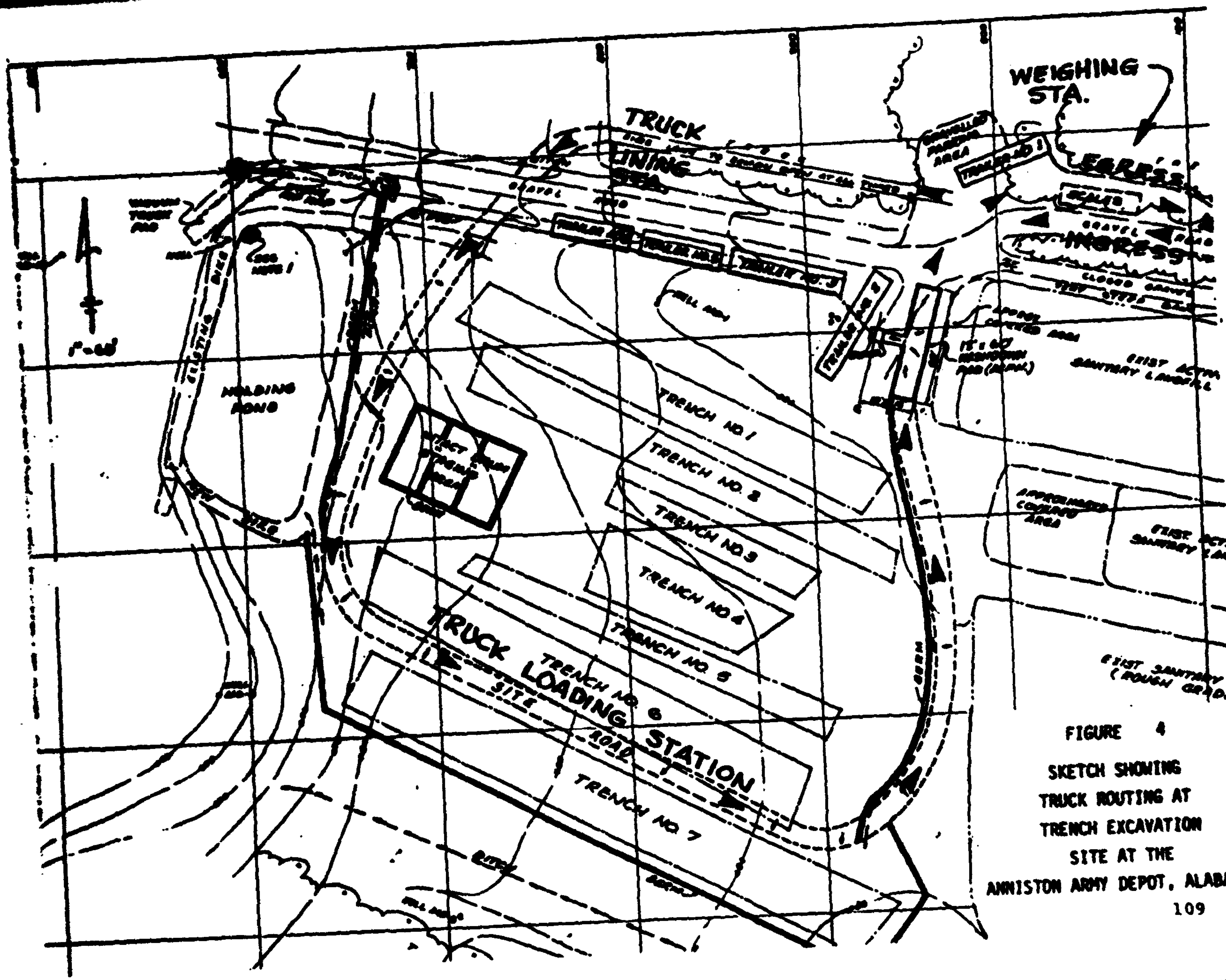


FIGURE 4

SKETCH SHOWING
TRUCK ROUTING AT
TRENCH EXCAVATION
SITE AT THE
ANNISTON ARMY DEPOT, ALABAM

Personnel training for the AAAD project involved preliminary hazardous waste training, site specific safety training, first aid instruction, and daily safety meetings for all on-site personnel. The training emphasized the hazards present at the site, as well as the physical hazards associated with heavy equipment and construction-related work. The training also stressed the methods used to minimize these hazards and emergency procedures to be followed in the event of a mishap. Safety meetings were held daily prior to starting work to discuss relevant events which occurred the previous day and to brief the work crew on the intended plan of operation for the day. These meetings served to emphasize the safety requirements of the project and to maintain a high level of safety consciousness on the part of the work crew.

Protective clothing for the work activities was based upon known and suspected chemical and physical hazards at the site. An initial hazard analysis of the site was performed in accordance with the approved Safety Plan. The OSHA permissible exposure limits (PELs) and the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit values (TLVs) for the contaminants of concern were utilized in all decision related to personal safety. Specific action levels were as follows:

0 - 5 ppm above background	Level C
5 - 500 ppm above background	Level B
500 - 1000 ppm above background	Level A

The basic safety equipment included a modified Level C protection which consisted of Tyvek coveralls; steel-toed, steel-shank PVC work boots; PVC heavy-duty gloves; and hard hat with a face shield. The Tyvek garment was fastened around the outside of the boots with duct tape to prevent liquids from entering the boot. During the cold months, a cloth coverall was occasionally worn over top of the Tyvek garment.

The respiratory protection program involved several pieces of equipment. During the initial entry into Sites Z-1 and Z-2 the hazard presented by airborne contaminants was unknown, therefore supplied air was used by all crew members. The supplied air systems consisted of Self-Contained Breathing Apparatus (SCBA) and airline respirators connected to large air cylinders. The airline respirators were used by crew members, such as the truck preparation technicians, whose duties did not require a great deal of mobility.

The level of air contamination at each site was determined through the data provided by the Foxboro Miran 801 Infrared Analyzer and/or the Century Organic Vapor Analyzer (OVA). When the level of contamination was determined to be within the allowable limits for safe use of cartridge respirators, as defined in the approved Safety Plan, the level of protection was downgraded and half-face organic vapor cartridge respirators were used. (It should be noted that crew members using supplied air operated the trucks during the initial entry phases. Only after the level of protection was downgraded were the regular truck drivers, trained in the use of their respirators, allowed to drive their trucks into the loading zone.)

Air monitoring was conducted continuously at the excavation face of Site Z-1 by the Miran 801 Infrared Analyzer and in the various work zones to monitor the air quality. On several occasions during the excavation of Site Z-1 organic concentrations in the air in the immediate vicinity of the excavation exceeded the limits specified for Level C protection. At those times it became necessary for the site crew to revert to Level B (supplied air) protection as specified in the approved Safety Plan. The backhoe operator and the technicians working at the active excavation face were the only workers who operated in areas where high concentrations of organics occurred with regularity. The technicians handling the tarping operations came in closest contact with the actual waste material and were required to utilize Level B protection on several occasions. None of the air quality excursions lasted for more than two hours, after which cartridge respirators were once again safely used. It is important to note that the exposure limits previously described are established for persons without respiratory protection. Since all of the site workers, at a minimum, wore cartridge respirators at all times when in the work zones, they were never actually exposed to these levels.

A personnel monitoring system consisting of absorption media and air sampling pumps was utilized as an additional source of information regarding personnel exposure to the organic constituents of the waste material at the site. The absorption media, which consisted of two charcoal tubes in series and an impinger which contained methanol-sodium hydroxide solution, as well as the sampling pumps, were worn by workers in the various activity zones. In addition, a monitoring station, consisting of the same media and sampling pump setup, was established at the active face of the excavation. The purpose of this apparatus was to collect air samples which were analyzed at an industrial hygiene laboratory to calculate time-weighted averages for personnel exposure.

Prior to working at the ANAD, each site worker was required to undergo a complete physical examination as specified in the approved Safety Plan. The examination was to establish a baseline medical history prior to work at the site and to qualify the individual for use of respiratory protection gear. Results from physical examinations conducted at the completion of the project indicate that there was no adverse exposure suffered during the course of the excavation activity.

AIR MONITORING PROGRAM

The initial site hazard assessment established airborne contaminants consisting of organic compounds as the greatest potential hazard to on-site personnel. To ensure precise monitoring of this hazard, an exacting air monitoring program was designed and implemented at the project site.

In accordance with U.S. Army specifications for the ANAD project, a three-way air monitoring program was developed. The program consisted of:

1. A site perimeter, near-real time air quality monitor.

2. A continuous, on-site, real-time air quality monitor.

3. A personnel exposure monitoring system which yielded certified time-weighted averages (TWA's) within 24 hours.

In order to satisfy these requirements, a variety of instruments and sampling techniques were utilized.

The requirement for a site perimeter air monitoring system was met through the use of a Foxboro Miran 801, a user-programmable, multi-station infrared analyzer. The purpose of this requirement was to monitor any migration of organic vapors from the work site which might be occurring as a result of the field activities.

Twelve stations were located around the periphery of Site Z-1, each 30° apart (from a center point). Each of these stations consisted of a filtered hose outlet which was located approximately 3' above ground level and connected with an uninterrupted length of tubing around the site to the infrared analyzer. A separate length of tubing was run from each of the sampling stations. The stations (and sequence) to be sampled were programmed into the machine based upon the wind direction (obtained from the on-site weather station) and set to begin cyclic sampling for aromatic hydrocarbons resembling benzene, chlorinated hydrocarbons resembling chloroform, and phenol-like compounds resembling pure phenol. These three compounds were chosen as representative of the organic contaminant families which were expected to be found at the site. A vacuum pump pulled representative air samples through the tubing and into the infrared analysis cell.

Data resulting from the analyses were printed on the programming terminal. Each sampling required approximately 2.5 minutes; in this manner, a near real time data output was achieved. The data output listed station number, time of analysis, and concentrations of benzene, chloroform, and phenol in the sampled air parcel.

The Miran 801 was calibrated each day using laboratory standardized gases at various concentrations. The machines underwent a rigid certification procedure by USATHAMA to verify the quality of the data obtained from it. The calibration procedure consisted of connecting the laboratory standard gases to the sampling station furthest away from the analyzer (Station No. 7, approximately 800 feet away) and comparing the machine print out values against the known concentration of the standard gas.

The results from the Miran 801 analyses showed minimal off-site organic vapor migration. On occasion, a station was sampled just as a loaded truck was passed and a high value was recorded. Alarm levels based on established safe limits were programmed into the machine which activated an audible alarm whenever the levels were exceeded. This alarm sounded several times during the course of the project. In each case the circumstance which activated the alarm was of short duration.

The results of this air monitoring program indicated that there was minimal, if any, exposure of off-site personnel resulting from the migration of organic vapors. The limited escape of concentrated levels of organic vapors from the site can largely be attributed to the relatively low evolution of high concentration vapors generated by the work activity, as well as the high rate of dilution which resulted from the wind and open atmosphere of the site.

The second air monitoring instrument that was used at the site was the Century Organic Vapor Analyzer (OVA). This instrument is a lightweight, portable flame ionization detector which was used as a supplement to the Miran 801 to provide real-time data on air quality in the various work zones. The OVA operates by sampling the air continuously via an internal battery-run pump. The air sample is routed to a flame ionization chamber where it is mixed with a stream of hydrogen gas and burned. An electrode in the flame ionization chamber detects the amount of "burning" (or ionization) occurring and registers this as the amount of total organic vapor in the air stream. The results are registered on a hand-held meter. When the OVA is operated in this fashion, it is termed the Survey Mode and provides an instantaneous (approximately two-second lag time) readout of the apparent air quality in any given area.

The OVA was used by the Site Safety Officer to measure general air quality at the various work stations on the site. It was used principally at the excavation face to monitor the instantaneous release of organics as the buried wastes were uncovered. The measurements were used by the Site Safety Officer as supplemental information to the Miran 801 data to ensure personnel protection on the site. The OVA was also used during the initial entry operations to augment the Miran 801 data to assist in the decision logic of whether air quality met the OSHA limits.

The OVA was used by the Site Safety Officer to assist in accurately assessing the nature of the chemical hazards encountered at the site. This mode of operation is termed the Gas Chromatography (GC) mode which utilizes standard gas chromatography packed columns and allows the user to inject unknown gas samples into the OVA and obtain a printed chromatogram which is then compared to the chromatograms of known gas standards.

It should be noted that use of the OVA was not a contract requirement and that the methodology utilized was not USATHAMA certified. However in circumstances where both modes of analysis were utilized, the data obtained from the OVA was in general substantiated by the Miran 801. The instrument provided timely information which aided in the field decision processes.

The third component of the air monitoring program at ANAD was the personnel monitoring system briefly described earlier. Basically, this system consisted of a high-flow and low-flow air sampling pump which pulled air through two separate capture media. The two media were: 1) two carbon absorption tubes placed in series to capture the volatile organics and 2) a methanol-sodium hydroxide solution in an impinger to capture the phenol vapors. This setup was worn by site personnel at each work zone for the purpose of monitoring a time-weighted exposure to the measured constituents. The media was placed in the worker breathing zone. In addition, a permanent monitoring setup was placed in the backhoe and at the excavation face to measure the amounts of contaminants at these two locations. The sampling media were sent by bus in a lock box to Environmental Health Laboratories, a certified industrial hygiene laboratory located in Macon, Georgia, for analysis each day. The results were then sent back to the Site Safety Officer to augment the Safety Plan and for future reference in WESTON's Corporate Safety Program.

CLOSURE

In order to complete closure of the two excavation sites at the Anniston Army Depot, it was necessary to implement a sampling and analytical plan to determine the concentrations of specific residual contaminants in the soil subsequent to excavation operations. The levels of residual contamination indicated whether further excavation was warranted or whether closure could be implemented. The original Closure Plan, as specified by the Request for Proposal, required that the entire site be excavated to two feet below the apparent bottom of the trenches and allowed to remain exposed to the atmosphere for a minimum of 30 days in order to allow residual organics to volatilize. After this period, representative soil samples were to be obtained and analyzed for specific contaminants via USATHAMA certified methodology to establish the effectiveness of the excavation process.

As a result of discussions with the Alabama Department of Environmental Management, USATHAMA and the Project Officer for the Corps of Engineers, WESTON was allowed to implement a phased closure of the site. In this approach, soil samples were obtained from the trenches which had been previously excavated and closure procedures were approved based on the results of the analysis of these soil samples. In this manner, specific trenches were being subjected to closure operations while additional trenches were being excavated. These procedures allowed optimal use of on-site personnel and equipment. Phased closure of the trenches also minimized the area of excavation which was subjected to the high intensity rainfall that occurred during the majority of the excavation activities, thus minimizing the quantity of contaminated stormwater which required treatment prior to disposal.

Individual closure plans, including the soil analyses of the specific trench areas involved, were submitted to State personnel for written approval prior to initiation of actual closure procedures. WESTON's authorization to initiate individual closure activities was received from the COE site representative only after written approval of such activities had been received from the State of Alabama Department of Environmental Management.

The USATHAMA certified soil analysis program indicated that, in general, soil contaminant levels fell below the analytical detection limits and therefore most areas of the trench bottoms on Site Z-1 required no further excavation. Isolated areas in Trenches 4 and 1 demonstrated elevated organic concentrations. Soil from those areas indicating a potentially high level of contamination was scraped via bulldozer and removed with a backhoe to a level of approximately two feet below existing grade to remove residual contamination. Post-excavation readings with the OVA were compared with that of background readings in the "clean" trench areas. When these readings approached the levels consistent with background, the trench area was submitted for closure. Upon State and COE written approval, the trenches were closed. Isolated soil samples were obtained from the "hot spots" immediately after the scraping operation and submitted along with the samples obtained prior to scraping. These samples verified the OVA results.

During the excavation/closure proceedings, contamination was prevented from migrating from working areas into previously excavated areas by means of berms and visqueen cover. As an additional measure to ensure removal of any potential contamination, the bottom of each completed trench was scraped prior to harrowing.

After all trenches were excavated, the exposed soil was harrowed to a depth of approximately six inches to permit volatilization of any remaining contamination. After an exposure period of at least two weeks, the soil was covered with a visqueen seal until closure was completed.

DEMOBILIZATION AND SITE RECLAMATION

After completion of the trench excavation, removal of all other potentially contaminated soils and receipt of appropriate approvals, the work site was demobilized and the reclamation program was instituted. The objectives of this phase were to clean and remove work equipment and restore the disposal site for any future use.

All equipment employed within the original zone of contamination (the "hot zone") was decontaminated and removed from the site. Decontamination activities were performed on the existing decontamination pad. All visible contamination was removed by application of high-pressure water. The surface was then rinsed with an appropriate decontamination solution as defined in the Technical Plan. After all contaminated site equipment was cleaned, the decontamination pad was washed down.

All potentially contaminated materials within the "hot zone" were removed prior to demobilization. Materials within the holding pond were solidified and the contaminated pond sediment was excavated for disposal. The gravel road leading to the decontamination pad was excavated for disposal. Any remaining miscellaneous materials which could have been potentially contaminated were removed for proper disposal.

Water from decontamination activities was collected in the existing decontamination sump and transported to the Depot wastewater treatment facility.

Sludges remaining in the sump were removed for disposal by the vacuum truck. The pad was bulldozed and loaded onto trucks for disposal at the Depot refuse disposal facility.

The four operations trailers adjacent to the excavation were dismantled and removed to the truck staging area. Upon completion of all site activities, they were ultimately removed from the Depot. The command trailer remained in place until the conclusion of all site activities, including reclamation.

After all contaminated materials were removed and trailers were relocated to the staging area, reclamation of the site was initiated. Reclamation consisted of construction of a compacted cover over the original trenches, topographic modification and revegetation.

Borrow material for reclamation was obtained from areas adjacent to the site. The hill south of the site contributed most of the borrow materials. Minor amounts of fill were obtained from areas north of the excavated area.

Materials from the borrow area were removed in a manner which prevented the destruction of existing monitoring wells. Excavation in the vicinity of the wells allowed an undisturbed area to be left around the wells to prevent damage by heavy equipment. The remaining soil surrounding the wells was removed by hand to a level equivalent to the constructed grade elevation.

Top soil for final covering of the reclaimed area was scraped from the hill south of the site and stockpiled for later use. Underlying soil from the hill was then excavated for use as fill.

Movement of borrow materials to the excavated areas was accomplished by means of two pans. Prior to initiation of the filling operations, the temporary gravel road north of the site was scraped and the gravel was removed to a storage area for later use. The original road was regraveled subsequent to the completion of the finished grading.

As the borrow materials were emplaced into the trench, they were compacted with a sheepsfoot roller. The roller was utilized continuously as materials were delivered to the site to provide compaction of all disturbed soils. These compacted clay soils provided a relatively impermeable cap for the excavated site.

Materials were deposited so as to achieve a "naturalized" topography. The excavated area was backfilled to form a gentle slope (less than 20:1). The steeper slope will conform more closely to existing natural topography. The overall effect of the grading was to achieve a shallow westward slope with approximately parallel contours which steepen slightly on its western edge to permit good drainage over the site into a natural drainage way.

After the final contours were roughly graded, top soil was spread across the site. Top soil obtained from adjacent areas was emplaced uncompacted, across the original site.

After the topsoil was emplaced, the area was fertilized with 600 pounds per acre of 13-13-13 fertilizer and agricultural lime was added at 4400 pounds per acre. A seed mixture of 30 percent Kentucky 31 Tall Fescue and 70 percent Hulled Bermuda was applied at 60 pounds per acre. The seeded area was then mulched with one and one half tons per acre of straw or hay mulch applied simultaneously with the grass seed.

WESTON

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INCINERATION OF EXPLOSIVES CONTAMINATED SOILS

by

John W. Noland, P.E.
Senior Project Engineer
Roy F. Weston, Inc.
Weston Way
West Chester, Pennsylvania 19380
215-692-3030

and

Wayne E. Sisk
Project Officer
COR
USATHAMA
Attn: DRXTH-TE-D
Aberdeen Proving Ground
Edgewood Area, Maryland 21010
301-671-2054

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WESTON

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INTRODUCTION

The U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), located in the Edgewood area of Aberdeen Proving Ground, Maryland has dual Army responsibility for lethal chemical demilitarization and installation restoration. It also serves as the lead agency within the U.S. Army Materiel Development and Readiness Command (DARCOM) for pollution abatement and environmental control technology development.

In this role, USATHAMA routinely conducts generic research and development (R&D) studies with wide application to current U.S. Army environmental problems. The incineration of explosives contaminated soils (IECS) project is an example of one of the many successful R&D efforts USATHAMA has conducted throughout the years.

BACKGROUND

Large quantities of wastewater are generated during the manufacturing of explosives and propellants; the loading, assembly, and packing of munitions; as well as demilitarization and washout operations. These wastewaters (referred to as "red water" or "pink water" due to their characteristic color) contain varying concentrations of explosives. Standard practice in the past has been to dispose of these wastewaters in settling lagoons at various U.S. Army installations. Although current practice provides for in-plant treatment of these wastewaters, the inactive settling lagoons at numerous U.S. Army installations are a source of potential groundwater contamination.

I-4007-4590A

WESTON

USATHAMA is currently evaluating a number of potential remedial action options for future implementation. One option has emerged as the most promising in the near term (i.e., for installations requiring remedial action within the next five years). This option is excavation of the soils, followed by thermal processing in a rotary kiln incinerator. The U.S. Army routinely incinerates pure explosives and propellants; however, previous to this project this technology was undemonstrated on explosives contaminated soils.

PROJECT OBJECTIVES

The objectives of the Incineration of Explosives Contaminated Soils (IECS) project were as follows:

- The primary objective of these tests was to demonstrate the effectiveness of incineration as a decontamination method for explosives contaminated soils.
- The secondary objectives of the project was to:
  - Develop a data base and appropriate correlations for designing and predicting the performance of the incinerator as a decontamination method;
  - Determine the fate of the explosives and metals in the contaminated soils during/after incineration; and
  - Measure pollutant levels in the stack gas to determine the air pollution control devices that would be required for incinerators that may be used in the future to incinerate explosives contaminated soils.

PROJECT DESCRIPTION

In August 1982, USATHAMA commissioned Roy F. Weston, Inc. (WESTON) to develop and implement a program to demonstrate the effectiveness of rotary kiln incineration in decontaminating explosives contaminated soils. This program consisted of seven tasks:

- Task 1 - Incineration Equipment/Test Site Selection.
- Task 2 - Soil Characterization/Reactivity Testing.
- Task 3 - Development of Detailed Test Plan/Safety Plan.
- Task 4 - Environmental Permitting.
- Task 5 - Evaluation of Materials Handling Procedures.
- Task 6 - Incineration Testing.
- Task 7 - Evaluation of Results.

I-4007-4590A

The IECS Project Schedule is presented in Figure 1. The following subsections summarize the results of the previously mentioned seven tasks.

INCINERATION EQUIPMENT/TEST SITE SELECTION

After a comprehensive survey of rotary kiln manufacturers to determine the availability of appropriately sized test units, ThermAll, Inc. of Peapack, New Jersey was selected as the incinerator subcontractor for the project. A major innovation of this project was the decision to use a "transportable" incinerator (i.e., equipment disassembled, loaded on trucks, shipped to the test site, and reassembled) as opposed to a "mobile" incinerator (i.e., truck mounted) or shipment of the contaminated soils to a commercial facility.

The test site selected was a U.S. Army installation in Illinois which provided the following advantages:

- Remote location well isolated from populated areas.
- Close proximity to contaminated soils.
- Well controlled access and security.

SOIL CHARACTERIZATION/REACTIVITY TESTING

In order to maximize the usefulness of the results of the project, USATHAMA decided to test contaminated lagoon soils from two separate installations with widely varying characteristics (see Table 1). The two installations selected provided ranges of soil characteristics typical of most other U.S. Army installations.

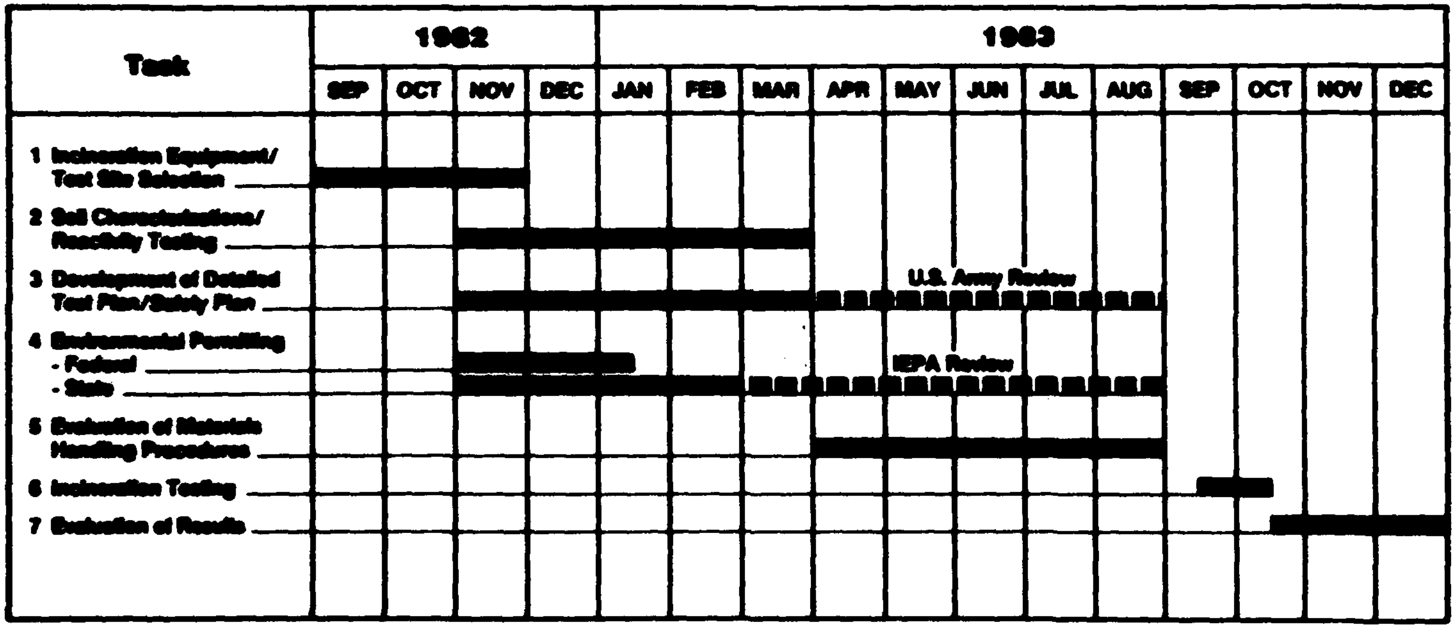


FIGURE 1 PROJECT SCHEDULE

WESTON

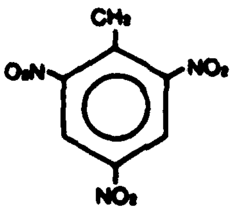
Table 1

Characteristics of Explosives Contaminated Soils

Description	Soil Type "A"	Soil Type "B"
Soil Matrix	Sand	Clay
Moisture Content	12 - 26%	25 - 30%
Ash Content (as received)	44 - 83%	54 - 66%
Explosives Content[1] (dry basis)		
- TNT	9 - 41%	5 - 14%
- RDX	<0.02%	3 - 10%
- HMX	Not Detected	0.6 - 1.4%
- Other	≤0.03	<0.06%
- Total Explosives	9 - 41%	10 - 22%
Heating Value (as received)	50 - 2,400 Btu/lb	600 - 1,200 Btu/lb

[1]See Table 2 for the molecular structures of the explosives.

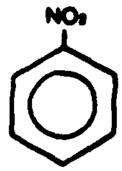
TNT



$C_7H_5N_3O_6$

2,4,6 Trinitrotoluene

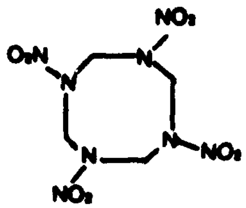
NB



$C_6H_5NO_2$

Nitrobenzene

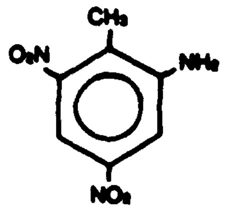
HMX



$C_4H_8N_8O_8$

1,3,5,7-Tetranitro-Octahydro-1,3,5,7-Tetracyclooctane

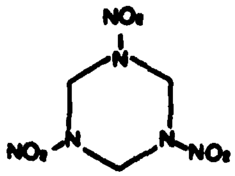
2-Amino



$C_7H_7N_3O_4$

2-Amino-4,6 Dinitrotoluene

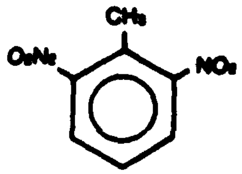
RDX



$C_3H_6N_6O_6$

1,3,5-Trinitro, Hexahydro-1,3,5-Triazine

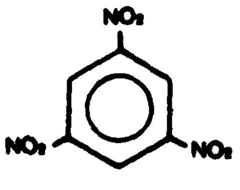
2,6 DNT



$C_7H_6N_2O_4$

2,6-Dinitrotoluene

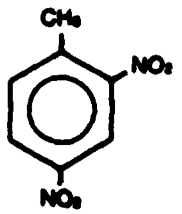
TNB



$C_6H_3N_3O_6$

1,3,5-Trinitrobenzene

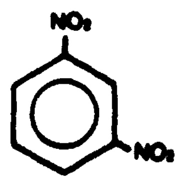
2,4 DNT



$C_7H_6N_2O_4$

2,4-Dinitrotoluene

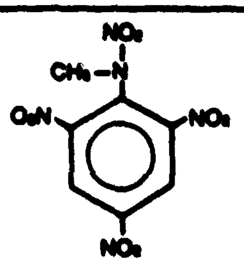
DNB



$C_6H_4N_2O_4$

1,3-Dinitrobenzene

Tetryl



$C_7H_5N_5O_8$

Tetranitromethylaniline

TABLE 2 MOLECULAR STRUCTURE OF EXPLOSIVES

The contaminated lagoon soils are hazardous because they exhibit the characteristic of reactivity (i.e., potential for detonation or explosion). Testing conducted at Allegany Ballistics Laboratory (ABL) in Cumberland, Maryland *confirmed* that the lagoon soils are reactive and that special precautions were required in developing materials handling procedures and equipment design.

DEVELOPMENT OF DETAILED TEST PLAN/SAFETY PLAN

In order to provide for meaningful evaluation of the incineration test results, a test plan was developed and certain key parameters were selected to be controlled and held at various levels during the testing. These key parameters were:

- Soil feed rate.
- Temperature in the primary combustion chamber.
- Temperature in the secondary combustion chamber.

These key parameters were selected since they directly relate to the economics of incineration (i.e., how much can be burned, how quickly can it be burned, and how much fuel is required?).

Other test variables were held constant to the extent possible. Test variables that could not be held constant were measured during the test as illustrated in the test plan schematic diagram (Figure 2).

From the outset, USATHAMA assigned personnel safety the highest priority for this project. In this regard, a detailed site plan and safety submission were developed and reviewed and approved by the Department of Defense Explosives Safety Board.

ENVIRONMENTAL PERMITTING

Recognizing the importance of Federal and state environmental concerns, the IBCS project was structured to be fully responsive to the requirements of the Resource Conservation and Recovery Act (RCRA) of 1976 and the Illinois Air Pollution and Hazardous Waste Management Regulations. As shown in the project schedule, the environmental permitting was an extremely rigorous and time-consuming process.

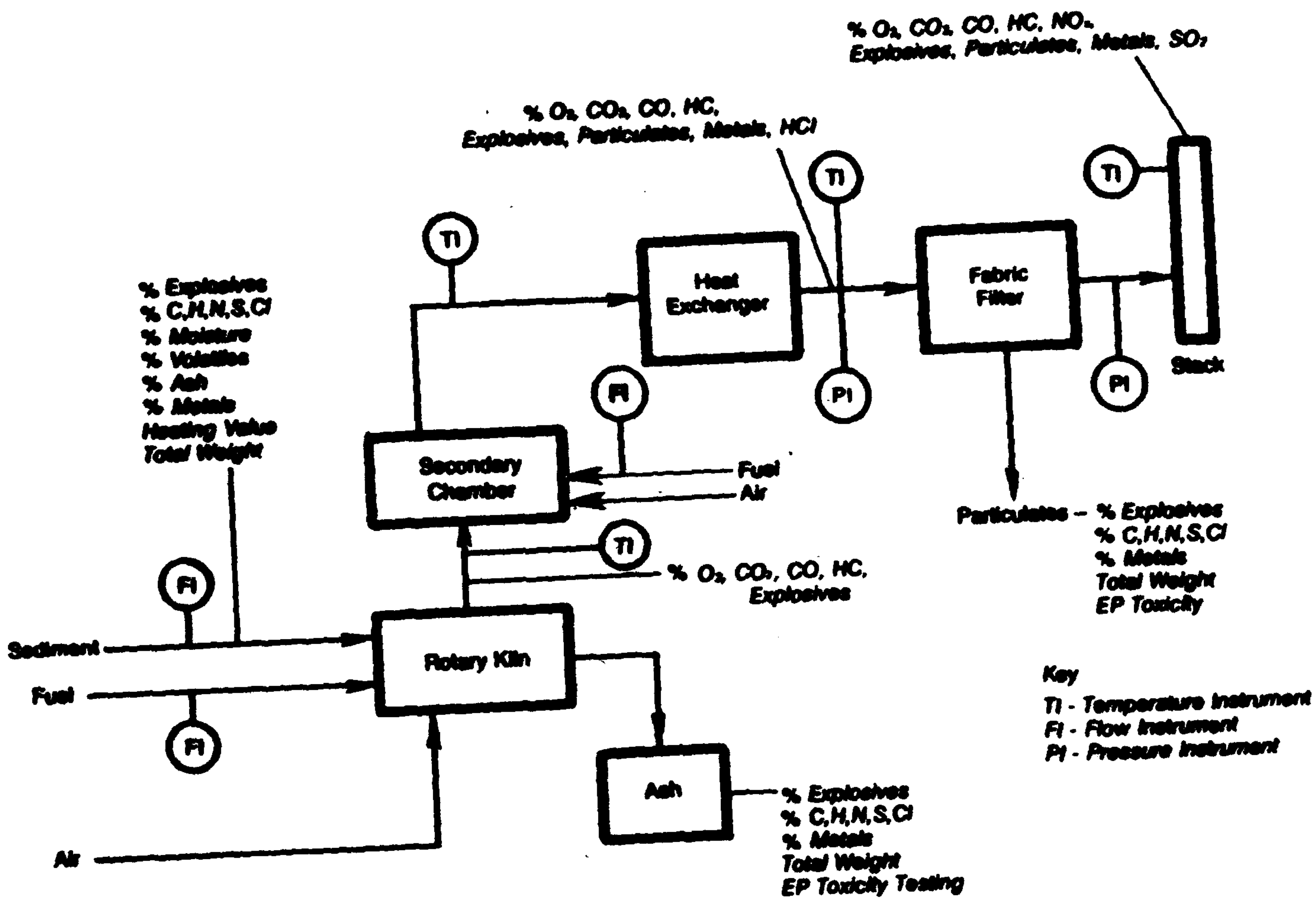


FIGURE 2 INCINERATION TEST SCHEMATIC DIAGRAM

EVALUATION OF MATERIALS HANDLING PROCEDURES

The primary objective of this task was to evaluate, design, and implement materials handling procedures that emphasized personnel and environmental safety. There were four major goals:

- Minimize personnel contact with the lagoon soils.
- Avoid confining the lagoon soils (which could lead to detonation).
- Avoid any initiating forces (i.e., friction, heating under confinement, etc.).
- Contain any spills and minimize contamination of clean areas.

The test plan was developed assuming the use of a screw conveyor to feed the contaminated soils into the incinerator. However, subsequent soil reactivity testing at ABL led to cancellation of the screw conveyor due to safety considerations. A soils handling protocol and a bucket feed system was designed specifically for this test program which met all of the test objectives and safety requirements. During the course of the test program, the feed system cycled over 4,000 times without a single failure. The bucket feed system is illustrated in Figure 3.

INCINERATION TESTING

The incineration testing commenced on 19 September 1983. Nineteen daily tests were completed in 20 consecutive calendar days with no time lost due either to incineration or sampling equipment failure. Table 3 provides a summary of the test conditions for each of the 19 runs. Since explosive contaminated soils had never been incinerated before, a preliminary test run (Test Run No. 1) was conducted at the proposed maximum feed rate (500 pounds per hour) and proposed minimum primary kiln temperature (800°F) to see if explosives breakthrough would occur in the stack gas. No explosives were detected in the stack gas; however, explosives were detected in the kiln ash, fabric filter ash, and in the flue gas entering the secondary chamber. Therefore, subsequent test runs were conducted at lower feed rates and higher primary kiln temperatures to ensure that explosives would not be emitted to the environment.

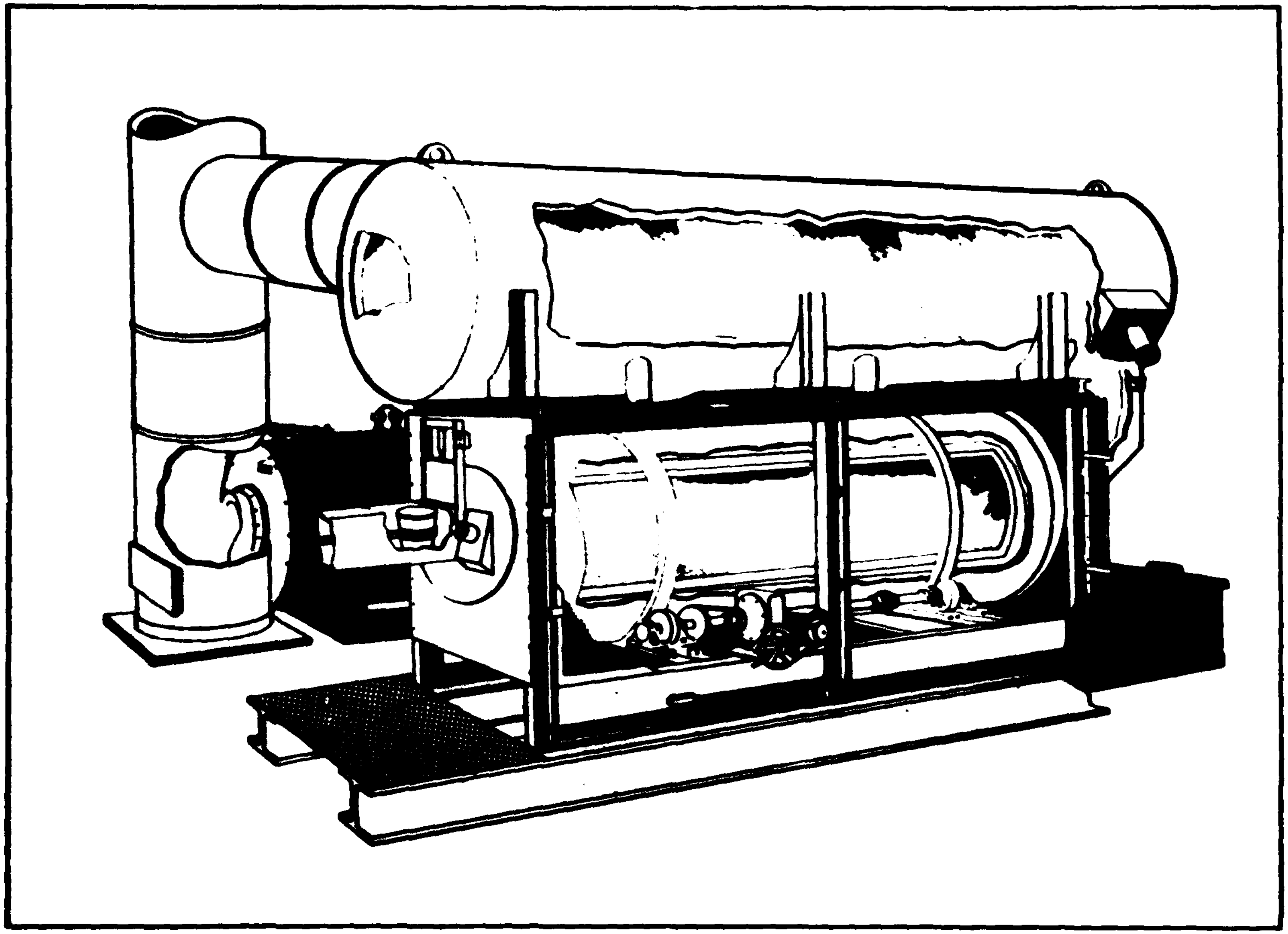


FIGURE 3 CUTAWAY SECTIONAL VIEW OF THE THERMALL INCINERATOR

Table 3

Definition of Test Matrices and
Summary of Controlled Process Variables

TEST RUN NO.	TEST DATE	MATRIX NUMBER	SOIL FEED RATE (lb/hr)	PRIMARY KILN TEMPERATURE (°F)	SECONDARY CHAMBER TEMPERATURE (°F)	SOIL TYPE (A or B)
1	9/19	0-1	500	800	1400	A
3	9/21	1-1	300	1200	1600	A
15	10/4	1-2	350	1200	1600	A
2	9/20	1-3	400	1200	1600	A
5	9/23	1-4	300	1400	1800	A
8	9/27	1-5	350	1400	1800	A
4	9/22	1-6	400	1400	1800	A
10	9/29	1-7	300	1600	2000	A
14	10/3	1-8	350	1600	2000	A
12	10/1	1-9	400	1600	2000	A
7	9/26	2-1	300	1200	1600	B
19	10/8	2-2	350	1200	1600	B
17	10/6	2-3	400	1200	1600	B
13	10/2	2-4	300	1400	1800	B
16	10/5	2-5	350	1400	1800	B
6	9/24	2-6	400	1400	1800	B
9	9/28	2-7	300	1600	2000	B
11	9/30	2-8	350	1600	2000	B
18	10/7	2-9	400	1600	2000	B

After the formal testing was completed on 8 October 1983, an additional 25,000 pounds of lagoon soils were incinerated from 10 to 15 October 1983 (64 actual hours of incinerating soils). The objectives of burning the additional lagoon soils were twofold:

- Thermally treat all lagoon soils that had been excavated but not required during the formal testing.
- Determine the operational characteristics of the incinerator system under a long-term, steady-state production mode of operation.

RESULTS

The IECS test project was extremely successful as demonstrated by the following results:

- It was demonstrated that a "transportable" incineration system could be disassembled, transported approximately 1,000 miles, be reassembled, and fully operational within two weeks.
- Nineteen days of formal testing were completed within 20 consecutive calendar days with no lost time due to equipment failure.
- An additional six days of operation were performed at steady-state conditions with no downtime due to equipment failure or malfunction.
- An explosives destruction efficiency of greater than 99.99 percent in the primary kiln ash.
- An explosives destruction efficiency of greater than 99.9999+ percent in the fabric filter ash.
- No detectable explosives in the stack gas. Therefore, an overall destruction and removal efficiency (DRE) of 100 percent.
- Stack emissions were in compliance with all Federal and state regulations including:
    - Sulfur dioxide (SO_2).
    - Hydrogen chloride (HCl).
    - Oxides of nitrogen (NO_x).
    - Carbon monoxide (CO).
    - Particulates.

- Ash residues are not hazardous due to the characteristic of EP toxicity or any other criteria, and application has been made to the Illinois EPA to land apply the ash residues in an area adjacent to the incineration test site.

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POLYMERIC LINER SELECTION FOR MILITARY WASTE IMPOUNDMENTS

Jonathan W. Braswell, Gregory M. Gibbons, Timothy G. Shea, Ph.D.
Engineering-Science
10521 Rosehaven Street
Fairfax, Virginia 22030
(703) 591-7575

INTRODUCTION

The use of polymeric membrane liners to line or cap waste impoundments is receiving increasing attention. The liners are essentially impermeable to water and thus are assumed to be capable of providing complete containment of the waste fluids; however, while polymeric membrane liners have been used successfully for many years in water impoundments, little experience is presently available for the use of these liners with wastes. Of particular concern is the effect of the contained waste on the physical properties of the liner material - the compatibility of the liner with the waste. Moreover, the compatibility testing performed to date has utilized methodologies unique to each investigation, and published results tend to be general and inconclusive.

Until the last decade, lagooning was the accepted method of disposal of wastewaters from the manufacture of munitions. As a result, explosive compounds such as TNT and RDX are found in many of the lagoons that have been used by the Army for this purpose. Because these compounds have been defined as hazardous under RCRA, it may be necessary to remove, transport or dispose of the lagoon sediments or the residuals from the treatment of these sediments from many of the lagoons.

It was assumed that synthetic liners would be used in many of these clean-up operations, but synthetic membrane liners may or may not be compatible with the chemical compounds found in these sediments. Based on existing compatibility data, there is reason to believe that solvents such as TCE would be deleterious to the service life of commercially available synthetic membrane liners. The available information on the

Cont

compatibility of synthetic liners with the explosives such as TNT and RDX is limited and contradictory.

The described work was performed for the United States Army Toxic and Hazardous Materials Agency as part of their In-Situ Treatment Technology Program. This work was done to provide initial polymeric liner compatibility data for selected explosives and solvents, in order to determine the applicability of polymeric liners for the cleanup and restoration of impoundments containing wastes from the manufacture of explosives.

MANUFACTURE OF POLYMERIC LINERS

The synthetic liner industry has a distinct three-step hierarchy, and a knowledge of the organization and flow of goods in the industry is necessary for the selection of candidate liners for compatibility testing. The three levels in the industry are:

1. Manufacture of resins;
2. Manufacture of roll goods; and
3. Fabrication of sheets.

A single company may perform more than one of these functions. Some roll good producers also fabricate sheeting or manufacture their own resin. In general, however, the manufacturing process follows the above sequence.

Synthetic liners are classified by the base polymer. In blends or alloys the main polymer is used for classification. Due to the specific formulation produced by each manufacturer, the properties of one manufacturer's resin may differ from the same type of resin produced by another manufacturer. Resin manufacturers produce the raw materials (polymers) that form the base of the membrane. To the basic polymer (e.g., polyvinyl chloride or chlorinated polyethylene), the resin manufacturers add compounding ingredients specific to their formulation. Compounding ingredients include plasticizers, crosslinking (vulcanizing) chemicals, carbon black, pigments, fillers, biocides and antidegradents. The resin is sold to a roll good producer or used internally.

Roll good manufacturers use the resin to produce rolls of liner material. The roll good manufacturer will add to the resin additional compounding ingredients specific to his formulation and then form this mixture into rolls of material. The material is either extruded or calendered (rolled) into panels four to six feet wide and of varying length. Roll goods (liners) are produced either with or without reinforcing. Unreinforced (unsupported) liners are calendered or extruded in varying thicknesses. Typical thicknesses for most commercial liners are 15, 30 and 45 mils. Thicker liners are made by plying sheets of material. Reinforced (supported) liners can only be made by calendering. A fabric (weave) is sandwiched between two layers of the membrane material. The normal thickness for a reinforced liner is 36 mils.

Each manufacturer of roll goods adds compounding ingredients for their specific formulation; therefore, the characteristics of liners in the same class may vary from one manufacturer to another. Additionally, the compatibility of different manufacturers' products may differ with a given chemical, temperature and exposure environment.

The final step in construction of most membrane liners is the fabrication of large sheets of material. A sheet fabricator seams rolls of liner material into large panels, often 70 to 100 feet wide and of varying length. The length is dependent on maximum total weight allowed for transport and for ease of installation. The panels are made as large as practical, utilizing as many factory seams and as few field seams as possible. Minimizing the number of field seams both facilitates installation, and factory seams are preferable to field seams because they are made under controlled conditions and thus are of better quality.

For high density polyethylene (HDPE), there is no production of roll goods and subsequent factory seaming to fabricate sheets. HDPE sheets are extruded directly at widths of 22-1/2 and 34 feet without seams. These sheets are then seamed in the field during installation.

The seams in a liner often are the weakest point. Seaming techniques vary with liner material, fabricator and installer preference. A brief definition of the five commonly used seaming techniques follows:

- Thermal Weld - the process of joining thermoplastic sheets by the heating of areas in contact with each other to the temperature at which fusion occurs. The process is usually aided by a controlled pressure.

- Dielectric Weld - a heat weld where the heating is induced within sheets by means of radio frequency waves.

- Extrusion Weld - a heat weld where molten membrane material is injected into the seam. Extrusion welds are used with HDPE liners.

- Solvent Weld - the process of joining sheets by applying a solution of the liner compound emulsified in a solvent to areas in contact with each other. The solvent evaporates leaving a homogenous weld of the liner material, usually aided by controlled pressure.

- Adhesions - the process of joining sheets using specifically formulated flues to form a bond or seal, usually aided by controlled pressure.

LINER TYPES

Liners are classified by the main polymer utilized in their formulation. Table 1 is a description of the 10 liner types commercially available today and includes the abbreviation used for each. These liners are typically used for lining ponds and lagoons (except for

TABLE 1

DESCRIPTION OF POLYMERIC MEMBRANE LINERS CURRENTLY IN USE

TYPE	COMPOSITION	ADVANTAGES	DISADVANTAGES
Butyl Rubber	Co-polymer of isobutylene (97%) and small amounts of of isoprene. Usually vulcanized.	o High resistance to mineral acids o Good tensile strength o Ozone and weathering resistance o High tolerance to temperature extremes	o Highly swollen by hydrocarbons o Difficult to seam and repair; special vulcanizing adhesive required o Slightly affected by oxygenated solvents
Chlorinated polyethylene (CPE)	25 to 45% chlorine with 0 - 25% crystallinity. Usually unvulcanized.	o Resistant to many acids and alkalies o Good resistance to biological degradation o Ozone resistant o Often alloyed with PVC, PE and synthetic rubber	o Swells in high concentrations of aromatic hydrocarbons and oils
Chlorosulfonated polyethylene (Hypalon)	25 to 43% chlorine with 0 - 1.4% sulfur. Usually unvulcanized.	o Resistant to acids and alkalies o Ozone resistant o Resists molds and mildews	o Shrinks and hardens from exposure to UV light o Will soften at elevated temperatures o Low tensile strength o Poor resistance to oils o Swells in presence of aromatics

TABLE 1 (Continued) DESCRIPTION OF POLYMERIC MEMBRANE LINERS CURRENTLY IN USE

TYPE	COMPOSITION	ADVANTAGES	DISADVANTAGES
Ethylene propylene rubber (EPDM)	Terpolymer of ethylene, propylene and a minor amount of nonconjugated diene hydrocarbon. Usually vulcanized.	o Excellent ozone resistance o Tolerates extremes in temperature o Resistant to dilute solutions of acids, alkalies, silicates, phosphates and brine o Good abrasion resistance	o Not recommended for petroleum, aromatic or halogenated solvents o Special vulcanizing adhesives required for seaming and repair
Neoprene	Generic name of synthetic rubbers based on chloroprene. Vulcanized.	o Resistant to oils and acids o Mechanical properties similar to natural rubber with resistance to puncture and abrasion	o Vulcanizing cements required for seaming and repair
Polyethylene High density (HDPE)	Based on ethylene with 2-3% carbon black, density varies. Unvulcanized.	o Superior resistance to oils and solvents	o Special seaming tools required o Clear polyethylene readily degrades on outdoor exposure o Very stiff compared to other liner materials
Polyvinyl chloride (PVC)	Produced from vinyl chloride; 25-35% plasticizers, 1-5% chemical stabilizer, and microbiocide added. Un-vulcanized.	o Good resistance to many organic chemicals o Good tensile strength and elongation properties	o Affected by UV exposure o Heat of the sun can volatilize plasticizers o Susceptible to attack from hydrocarbons, oils and solvents

TABLE 1 (Continued). DESCRIPTION OF POLYMERIC MEMBRANE LINERS CURRENTLY IN USE

TYPE	COMPOSITION	ADVANTAGES	DISADVANTAGES
Oil resistant polyvinyl chloride (PVC-OR)	Similar to PVC with additional oil resistant compounding ingredients.	o Good resistance to many organic chemicals o Good tensile strength and elongation properties o Good oil resistance	o Affected by UV exposure o Heat of the sun can volatilize plasticizers
Ethylene interpolymer alloy	Alloy of elasticized polyolefin.	o Resistant to many chemicals o Good oil resistance o Good temperature service o Good weathering	o Not recommended for organics, especially aromatic o Low temperature limitations
-7- Polypropylene	Based on propylene with carbon black added. Unvulcanized.	o Resistant to many chemicals o Superior high temperature service o Good low temperature service o Good tensile strength	o Susceptible to UV and ozone attack o Difficult to seam in the field o Not recommended for oxidizing solvents

Sources: 1. Lining of Waste Impoundment and Disposal Facilities, SW-870, USEPA, Office of Water and Waste Management.

2. Engineering and Development Support of General Decon Technology for the DARCOM Installation Program, Task 7. Literature Search and Evaluation of Compatibility Testing of Waste Containment Barrier Materials.

polypropylene). The composition and relative advantages and disadvantages for each type of liner are also summarized in Table 1.

Table 2 is a listing of the roll good producers (and resin manufacturers) by type of liner. There are three main producers of roll goods for PVC, PVC-OR, Hypalon and CPE: Mainline; Pantasote; and B.F. Goodrich. Two resin manufacturers supply all the raw materials for Hypalon and CPE: Dow (CPE); and duPont (Hypalon will be made under a duPont patent until 1985). Ethylene interpolymer alloy (XR-5) is produced by only one firm, Shelter-Rite. XR-5 is a patented formulation of Shelter-Rite that reportedly has enhanced chemical resistance properties. EPDM is the only rubber liner material currently produced by more than one roll good manufacturer; namely, B.F. Goodrich and Carlisle. Rubber liner materials have been replaced in general usage by the more resistant plastic formulations. A single producer of polypropylene is included: General Tire using Hercules resin. Polypropylene is currently in the developmental stage for use in lining lagoons. It is widely used in tank lining because of its chemical resistance properties; however, it is not a feasible alternative for lining lagoons today.

EXISTING COMPATIBILITY DATA

Manufacturers are the primary source of liner compatibility data. Data is developed through manufacturers' specific testing, thus there is little agreement on "compatibility rating" criteria and ratings are often unsubstantiated with hard data. As detailed later in this paper, a standard, accepted test procedure has not been used in developing compatibility data, thus it is difficult to compare manufacturers' data bases.

General product material compatibility with specific compounds is useful in preliminary selection of liners for known wastes (with chemical breakdown of constituents). The Plastics Technical Evaluation Center (PLASTEC) of the U.S. Army Armament Research and Development Command (AARADCOM) located at Picatinny Arsenal in Dover, New Jersey has

TABLE 2

LINER TYPES AND MAJOR MANUFACTURERS

TYPE	ROLL GOOD PRODUCER	RESIN
PVC	B. F. Goodrich Mainline Pantasote	B. F. Goodrich B. F. Goodrich Pantasote
PVC-OR	B. F. Goodrich Mainline Pantasote	B. F. Goodrich B. F. Goodrich Pantasote
Hypalon (CSPE)	Stevens Pantasote B. F. Goodrich	duPont duPont duPont
CPE	Mainline Pantasote B. F. Goodrich	Dow Dow Dow
HDPE	Schlegel Gundle	Schlegel Phillips
Ethylene interpolymer alloy	Shelter-Rite	Hooker, Ferro
EPDM	Carlisle B. F. Goodrich	Proprietary
Butyl	Carlisle	Proprietary
Neoprene	Carlisle	duPont
Polypropylene	General Tire	Hercules

SOURCE: Telephone interviews and product brochures done extensive work in compiling compatibility data for polymers with energetics. Information has been gathered from reports and organized into a computer data base called COMPAT. Key words are used to retrieve the results of pertinent studies for a polymer material combination.

Table 3 is a summary of the results of a computer data base search performed by PLASTEC for polymer compatibility with TCE, TNT and RDX. Results of each study are listed by PLASTEC as being either compatible, marginally compatible, or incompatible. There were no data for TCE compatibility with the candidate liner types and data for TNT and RDX were limited to PVC, Hypalon, HDPE, EPDM and Neoprene. Hypalon and HDPE were noted as compatible for TNT in the studies; however, conflicting compatibility results were reported for TNT with PVC, EPDM, and Neoprene. EPDM and Neoprene were noted as compatible for RDX, while the results were conflicting for PVC and HDPE with RDX.

TEST SELECTION

Even when a polymeric liner has been properly installed, a failure of the liner can result from loss of liner integrity due to weathering or incompatibility of the liner with the chemical components of a waste. The selection of an appropriate liner must therefore focus on the degree to which the candidate liner can maintain its integrity over the projected life of the containment facility. Because liner performance data are limited, selections should be based in part on the results of exposure testing that simulates projected conditions.

An exposure test should be designed ideally as an accurate model of the intended application. The test should yield sufficient data that the results can be projected over the anticipated life of the facility, and the results should be useful for prediction of actual field performance. Unfortunately, because of the large number of variables that can affect liner integrity and the limited field data available on liner performance, no such liner exposure test has been developed. As a result, it is necessary to utilize a test procedure that best reflects a projected exposure condition and long-term liner performance. Moreover,

TABLE 3

PLASTEC COMPATIBILITY DATA SEARCH RESULTS

LINER TYPE	Chemical		
	TCE	TNT	RDX
PVC	No data	Conflicting data	Conflicting data
PVC-OR	No data	No data	No data
CPE	No data	No data	No data
Hypalon	No data	Compatible	No data
HDPE	No data	Compatible	Conflicting data
XR-5	No data	No data	No data
EPDM	No data	Conflicting data	Compatible
Neoprene	No data	Conflicting data	Compatible

SOURCE: PLASTEC, "A Compatibility Data Search, Plastic Materials vs. Energetics", 3 June 1982, ARRADCOM, Picatinny Arsenal the test procedure should be based upon accepted methods and have sufficient definition and control of test variables for reproducibility of results and comparison with results from other tests.

Liner Exposure Methods

Liner compatibility testing procedures focus on the method used to expose the liner samples to the test waste. Standard procedures for exposing liner samples to test wastes have only recently been developed. As a result, a wide variety of exposure methods and test variables are still being used. A majority of the liner exposure methods that have been used are adaptations of the American Society for Testing and Materials (ASTM) Method D-471 (Rubber Property Effect of Liquids), and ASTM Method D-543 (Resistance of Plastics to Chemical Reagents). These immersion tests, which are summarized in Table 4, have been used for both initial and long-term evaluation of liner compatibility.

In this type of test, specimens of a liner are immersed in the test waste and, after given exposure times, the liner specimens are removed and the changes in weight, dimensions and tensile properties are determined. Most immersion tests use the same immersion procedure; however, the test temperature, duration and evaluation criteria differ.

Most immersion tests are run at both ambient (23°C) and elevated temperatures. The elevated temperature is intended to simulate adverse conditions and to accelerate any deleterious effects that the waste may have on the liner. Unfortunately there is no concensus as to what this elevated temperature should be. As a result, elevated test temperatures used vary from 50°C to 100°C for the identified tests. The ASTM methods recommend exposure of materials at higher temperatures if elevated temperatures are expected in service.

Each immersion test uses a different test duration. The exposure period for long-term tests tends to vary from one to four months; however, exposure periods of one year or longer have been used. In all cases liner specimens are tested several times during the test so that the effect of the waste on the liner can be determined as a function of time. This procedure allows one to determine if the liner stabilizes after a given length of time.

There are not consistent criteria for evaluating the test results, specifically with respect to what degree of change is acceptable. For example, while one supplier uses compatibility criteria of no more than 3-percent change in weight and 10-percent change in tensile properties, another will allow a change of approximately 20-percent in analysis properties (assuming that the analysis results have stabilized).

In addition to immersion tests, a number of other exposure methods have been developed and used in attempts to more closely simulate actual field conditions. These additional tests are listed in Table 4 and can be characterized as landfill simulation, weathering and permeability tests.

Landfill simulators permit the liner to be exposed to a stratified or solid waste and to a hydraulic head. Landfill simulators have been used for long-term, research-oriented studies of one year to three years. By their nature, landfill simulators do not permit temperature to be controlled and intermediate assessments of replicate systems are expensive.

Weathering tests are used to address what combined effect a waste and climatic variations has on a liner. One supplier uses a heat lamp on a laboratory scale to simulate the effect of waste stratification and ultra-violet light on a liner. On a larger scale outdoor waste tanks and an exposure period of four years have been used to evaluate weathering effects, and DSET Laboratories has developed a patented, ASTM-approved, accelerated weathering test (which does not include exposure to waste).

The only membrane liner waste permeability test reported in the literature was a pouch test. In this test, waste was sealed in a pouch

TABLE 4

ADDITIONAL EXPOSURE METHODS

Reference	Test	Test Duration	Primary Analysis	Comments
Haxo, Henry (Matrecon)	Simulation cells	To 1,200 days	Weight change, ultimate elongation, S-100 modulus, volatiles, extractibles	Landfill simulators
	Weathering tests	To 1,231 days	Ulitmate elongation, S-100 modulus, extractibles	Exposure of membrane to weather
	Tub tests	4 years	Visual	Weathering of waste air interface. Most severely attacked area
	Pouch tests	1,000 days	Weight of liner pouch, pH and conductivity of water	Attempts to compare relative permeabilities
J. P. Stevens Company	Exposure tests, uncovered - sunlamp	7, 14, 21 and 28 days	Visual, weight change	Causes stratification of waste & exposure of waste/air interface
	Exposure test, covered - sunlamp	7, 14, 21 and 28 days	Visual, weight change	Lamp acts as heater
Styron and Fry	Lagoon simulation	12 months	Breaking strength, ultimate elongation	Lagoon simulation, pressurized to create 9 meters of head
DSET Laboratories	EMMAQUA Test method	Variable	Variable	Accelerated weathering test

SOURCES: (1) Haxo, ASTM 1982
(2) National Sanitation Foundation Proposed Standards
(3) Telephone interviews
(4) Desert Sunshine Exposure Tests, Inc.

made of a liner specimen and the pouch was immersed in de-ionized water. The flows of ions and water across the liner were then monitored.

TEST METHOD EVALUATION

Liner Exposure

Of the identified liner/waste exposure methods, only immersion tests and landfill simulator tests have been used extensively. Although weathering can have a significant effect on the long-term liner integrity, its impact is highly site-specific and difficult to simulate. Only the DSET Laboratories test is a fully documented and ASTM-approved procedure for measuring the effect of weathering, but it is only applicable to the simulation of weather effects and cannot be used to measure waste effects. Because of the inherent impermeability of polymeric liners, permeability is not considered to be a meaningful evaluation criteria (NSF). Additionally, no direct permeability test procedure is available. There are insufficient data on the pouch test to define what is measured by this procedure or its significance. Even though landfill simulators are designed so that leachate can be collected, permeability data from landfill simulators have yet to be published.

Immersion Tests

Immersion testing is the only widely-used procedure for determining the compatibility of polymeric liners with a test waste solution. This procedure evolved from standard ASTM test procedures for determining the compatibility of plastics and rubber with chemicals. A standard test protocol for liner compatibility with wastes has been recently proposed by the NSF. In addition to wide acceptance, the key advantages of immersion tests are the ability to fully define test parameters, limited exposure time and conclusive results. The key disadvantages are that field conditions cannot be fully simulated and solid or semi-solid wastes are difficult to test.

Because liner samples are exposed by immersing them in a test solution containing the waste, the area, equipment and waste quantity needed for immersion tests are small. As a result, it is feasible to expose multiple samples of a liner to a large number of variables such as waste concentration, exposure time, waste temperature and seam type.

Although exposure times of up to one year have been used for immersion tests, periods of one to four months are commonly used because any loss in liner integrity resulting from chemical reaction generally occurs within a short exposure time. Based on the compatibility data published by Exxon, the loss of integrity typically occurs within a month with concentrated chemicals. Additionally, accelerated exposure testing by increasing the temperature of the waste is used in both the initial ASTM procedures and in the proposed NSF test protocol.

Immersion tests, although widely used, do not simulate actual field conditions. In particular, the interface between the waste and atmosphere cannot be duplicated and the effect of waste concentration gradients on the liner cannot be investigated. As a result, some concern has been raised as to the degree that immersion test results can be projected to actual use. A second key disadvantage of immersion testing is the difficulty of using solid or semi-solid waste. Procedures for conducting immersion tests with solids or semi-solids have not been standardized, and it is unclear how well the test procedure can be adapted to solids.

<u>Landfill Simulator Tests</u>

Landfill simulation tests are used to simulate more closely actual field conditions and, as a result, to reflect more closely the actual effect of a waste on a liner. To date only a limited number of landfill simulator tests have been performed and a standardized or widely accepted landfill simulator procedure has not been developed. The key advantages of landfill simulator tests are the capabilities to simulate more closely field conditions and to use waste in a solid or semi-solid state. The disadvantages are that these units lack flexibility, are expensive and the validity of the results has not been demonstrated.

Unlike immersion tests where the liner specimens are simply suspended in a test waste solution, the liner specimen serves as the base of a simulated landfill in a landfill simulator. Factors such as exposure of the liner to a waste concentration gradient, a hydraulic head, and single side exposure can be simulated. It is assumed that such test results will more accurately reflect the interactions between the waste and the liner that occur in actual use and, thus, result in better predictions of long-term liner performance.

Because landfill simulators are constructed as tanks or columns with the liner specimen located at the base, the liner can be exposed to a solid waste without any special modification of the test procedure. Thus, test results from solids exposure should be comparable directly to liquid exposure results.

Although landfill simulators may better simulate actual field conditions, the volumes of material and waste required are large. Thus, fewer data points can be obtained and test variables are more difficult to control. Because each liner specimen must be installed in an individual test cell, a large number of test cells and large volumes of waste are required for a large scale test. As a result, fewer duplicate samples can be run and fewer variables investigated. Because only one side of the liner is exposed to the waste, longer exposure periods are required. In previous tests, exposure periods have been one year or greater. As a result, much less test data can be obtained within a given time and budget.

Of greater concern is the significance of the test results. Landfill simulators are still only an approximate model of actual service conditions. No standardized procedure has been developed and, until more field data are available, it will not be known how well landfill simulators actually reflect field conditions. Additionally, because of their size and long exposure times, it is difficult to closely control individual test variables during the test and, as indicated, fewer samples and variables can be run.

EXPERIENCE WITH THE NSF TEST PROTOCOL

The proposed NSF Test Protocol was selected for the liner compatibility testing with explosives and solvents. The NSF test has been proposed by the National Sanitation Foundation Joint Committee in their Draft Final Standards for Flexible Membrane Liners. The committee is composed of representatives of manufacturers, regulatory agencies, and users of liners. The standards represent a compilation of the views and ideas of many of the leading authorities on liners.

Immersion tests are the most widely used exposure method for liner compatibility studies and the only exposure method for which there is a standard procedure based on ASTM test methods. Immersion tests permit a large number of data points to be compiled, require a limited exposure period and permit close control over test conditions. The major drawback of immersion tests for the planned testing is the lack of past experience with the use of solid waste rather than a liquid waste; however, it would appear that immersion testing with solid waste would be feasible.

The proposed NSF liner compatibility test procedure was straightforward and no major problems were encountered during the testing period. The procedure permitted the screening of over 100 combinations of liners and test environments with good reproducibility of test results. Specific observations on the procedures used are presented below. The physical setup used to immerse the liner samples worked well and presented few problems. The immersion jars were easy to handle and allowed easy removal and replacement of test samples.

The most precise parameter used was weight change; however, it was not possible to obtain the precision implied in the NSF procedure for all liner/chemical combinations. The NSF procedure does not state a weighing precision but it does specify the use of a balance with a 1-mg precision. The liner samples immersed in water saturated TCE would lose weight while on the balance pan; thus it was not possible to obtain a steady weight to the third decimal point. This effect was also noted (to a much lesser degree) with the other samples.

Because of the changing weight, any variation in the time delay between drying and weighing would cause inconsistent weight readings. The NSF method calls for immediate weight readings because of this condition, and a standard procedure (as standard as possible) was used. Nonetheless, because it is impossible to reproduce exactly the drying-weighing procedure each time, the weights may deviate because of procedure as opposed to chemical effect. Even with the preceding considerations, the relative impact of weight changes during measurement was not significant.

Volume measurement was less precise than weight measurement because the method of measurement was not wholly satisfactory. The NSF proposed procedure specifies a dimensional measurement accuracy of 0.001 inches using a micrometer. A micrometer (caliper) is not suited for measurement of flexible material, especially to an accuracy of 0.001 inches. To measure length and width, the samples were held flat and every effort was made to not squeeze (and thus flex) the material; however, it was impossible to completely avoid flexing the liner sample. Also, the potential for flexing the samples increased after they softened in the water-saturated TCE solution. A second possible measurement error with the micrometer was not having it aligned perpendicular to the sample, thus altering the measurement.

LINER COMPATIBILITY

A projection of the potential compatibility of the five liner groups (PVC, CPE/Hypalon, XR-5, HDPE and EPDM/Neoprene) based on previously discussed results is presented below. The values are an assessment of the effect of the test chemicals on each liner based on the results of the screening test. A rating of one is used to indicate minimal effect and a rating of five to indicate failure of the liner.

HDPE appears to be potentially compatible with TNT and RDX, and may be compatible with TCE. The other four liner groups also appear to be potentially compatible with TNT and RDX; however, all four groups were found to be incompatible with TCE.

SUMMARY OF THE INITIAL SCREENING TEST RESULTS

	Relative Effect of Test Chemical[1]		
Liner Group	TCE	TNT	RDX
PVC	4	3	3
CPE/Hypalon	5	3	2
XR-5	5	2	2
HDPE	3	1	1
EPDM/Neoprene	4	2	2

[1] Relative effects are ranked from 1 (minimal) to 5 (failure).

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STABILIZATION OF CONTAMINATED SOILS BY IN SITU VITRIFICATION

C. L. Timmerman

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Pacific Northwest Laboratory
Richland, Washington 99352

STABILIZATION OF CONTAMINATED SOILS BY IN SITU VITRIFICATION*

C. L. Timmerman
Pacific Northwest Laboratory**
P.O. Box 999
Richland, WA 99352
509-376-4658

ABSTRACT

In Situ Vitrification is an emerging technology developed by Pacific Northwest Laboratory for potential in-place immobilization of radioactive wastes. The contaminated soil is stabilized and converted to an inert glass form. This conversion is accomplished by inserting electrodes in the soil and establishing an electric current between the electrodes. The electrical energy causes a joule heating effect that melts the soil during processing. Any contaminants released from the melt are collected and routed to an off-gas treatment system. A stable and durable glass block is produced which chemically and physically encapsulates any residual waste components.

In situ vitrification has been developed for the potential application to radioactive wastes, specifically, contaminated soil sites; however, it could possibly be applied to hazardous chemical and buried munitions waste sites. The technology has been developed and demonstrated to date through a series of 21 engineering-scale tests [producing 50-1000 kg (100 to 2000 lb) blocks] and seven pilot-scale tests [producing 9000 kg (20,000 lb) blocks], the most recent of which illustrated treatment of actual radioactively contaminated soil. Testing with some organic materials has shown relatively complete thermal destruction and incineration. Further experiments have documented the insensitivity of in situ vitrification to soil characteristics such as fusion temperature, specific heat, thermal conductivity, electrical resistivity, and moisture content. Soil inclusions such as metals, cements, ceramics, and combustibles normally present only minor process limitations.

Costs for hazardous waste applications are estimated to be less than $175/m^3 ($5.00/ft^3) of material vitrified. For many applications, in situ vitrification can provide a cost-effective alternative to other disposal options.

cu m, cu. ft.

INTRODUCTION

In situ vitrification (ISV) is the conversion of contaminated soil into a durable glass and crystalline waste form through melting by joule heating. The

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** Operated for the U.S. Department of Energy by Battelle Memorial Institute.

technology for in situ vitrification of contaminated soil is based upon electric melter technology developed at the Pacific Northwest Laboratory (PNL) for the immobilization of high-level nuclear waste. In situ vitrification was initially tested by researchers at PNL in August 1980 (U.S. Patent 4,376,598, Brouns et al. 1983). Since then ISV has grown from a concept to an emerging technology through a series of 21 engineering-scale (laboratory) tests and 7 pilot-scale (field) tests. The program has been sponsored by the U.S. Department of Energy's (DOE) Richland Operations Office for application to the Hanford Site.

The ISV development program utilizes three sizes of vitrification systems. The distinguishing characteristics of each system are power level, electrode spacing, and mass of block produced, as shown below:

System	Power	Electrode Spacing	Block Mass
Engineering	30 kW	30 cm	50-1000 kg
Pilot	500 kW	1.2 m	10 t
Large	3750 kW	5 m	350 t

The most recent pilot-scale test, completed in June 1983, vitrified a makeup site in which 25 kg of soil containing 600 nCi/g transuranic (TRU) waste simulated a radioactive area (or "hot spot"). The made-up source also contained mixed fission products with a total activity of 30,000 nCi/g, which exhibited a surface exposure rate of 100 R/h before they were emplaced in the test site. Test results showed that during vitrification the material was distributed fairly uniformly within an 8 t block. No radionuclides were released to the environment during the vitrification process.

With the successful completion of the radioactive test, the focus of the program has been directed to the design and testing of a large-scale system. This system is expected to be fabricated and acceptance-tested by early FY 1985.

Major advantages of in situ vitrification as a means of stabilizing contaminated soils are:

- safety in terms of minimizing worker and public exposure
- long term durability of the waste form
- cost effectiveness
- applicability to a wide variety of soils.

This paper describes the status of the ISV technology development program.

PROCESS DESCRIPTION

In situ vitrification is a process for stabilizing and immobilizing contaminated soil. To begin the process, which is shown in Figure 1, graphite electrodes are inserted vertically in the ground in a square array. Graphite

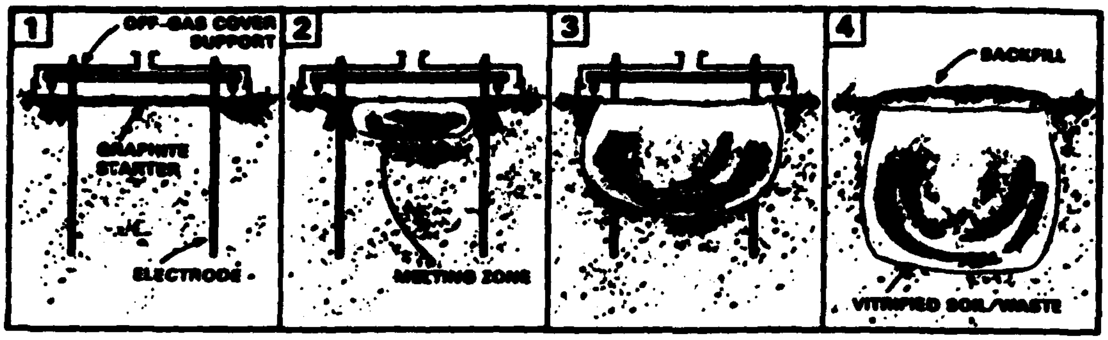

Figure 1. In situ vitrification process sequence.

is placed on the surface of the soil between the electrodes to form a conductive path. An electrical current is passed between the electrodes, creating temperatures high enough to melt the soil. The molten zone grows downward, encompassing the contaminated soil and producing a vitreous mass. Convective currents within the melt distribute the contaminants uniformly throughout the molten mass. During the process, off gas emitted from the molten mass is collected in a hood over the area and routed via piping to a treatment system, which scrubs and filters hazardous components. This hood, which operates under a vacuum, also provides support for the electrodes.

The principle of operation is joule heating, which occurs when an electrical current passes through the molten media. As this molten mass grows, resistance decreases. To maintain the power level high enough to continue melting, the current must be increased. This is accomplished by a transformer equipped with multiple voltage taps. The multiple taps allow more efficient use of the power system by maintaining the power factor (the relationship between current and voltage) near maximum. As heat losses from the melt approach the energy deliverable to the molten soil from the power supply, a melt depth limitation is reached. When power to the system is turned off, the molten volume begins to cool. The product is a block of glassy material resembling natural obsidian. Any subsidence can be covered with uncontaminated backfill to the original grade level.

A more detailed description follows, outlining the power system design and the off-gas treatment system.

Power System Design

The power system design is similar for all three scales of the ISV program. A transformer connection converts three-phase alternating current electrical power to two single-phase loads. The single-phase loads are connected to two of the diagonally opposing electrodes, which are arranged in a square pattern. This electrical arrangement creates a balanced electrical load on the secondary. The even distribution of current within the molten soil results in a vitreous zone almost cubic in shape, minimizing overlap among adjacent settings. Multiple voltage taps and a balanced load allow a near constant power operation, which shortens run time and thus reduces costs.

Off-Gas Treatment System

The off-gas containment and electrode support hood collects off gas, provides a chamber for combustion of any released pyrolyzed organics, and supports the four electrodes embedded in the soil. Much of the heat generated during the ISV process is released to the off-gas stream. The heat is removed in the off-gas treatment system, so that the temperature of the gas which exits after treatment approaches ambient.

The major types of treatment for the off-gas system include quenching, scrubbing, condensing, and filtering (see Figure 2). First the gas stream is cooled and scrubbed in two stages, using a quencher and a tandem-nozzle scrubber. The scrubber removes particles larger than 0.5 μm. The scrub solution in the saturated gas stream is removed by a vane separator followed by a condenser and another vane separator. To prevent any remaining moisture leaving the second-stage vane separator from condensing on the high efficiency particulate air (HEPA) filters, the off gas is heated to insure that the unsaturated gas stream is at a temperature above the dewpoint. Following the two stages of HEPA filtration, the off gas is discharged to the atmosphere through an induced-draft blower. Off-gas treatment for the pilot-scale radioactive test system is similar to that of the large-scale system. Both systems are trailer mounted and therefore mobile.

PERFORMANCE ANALYSIS

Performance of the ISV equipment and process and the quality of the waste form are discussed in this section. The power system has proven to be reliable and performs as designed. Startup and normal operation have been conducted with no signs of unstable behavior such as arcing, hot spots, or significant imbalance of the power load. The off-gas containment hood, developed for the pilot-scale system, has maintained negative pressure over the vitrification zone to prevent radionuclide losses outside the hood. The hood design incorporates a skirting of high-temperature resistant cloth which improves the seal around the edge. The off-gas system also performed very well. The system effectively contained off gases and removed all radioactive species during the radioactive field test.

Retention of elements within the vitrification zone has been high during pilot-scale tests. For example, retention of all radionuclides in the block during the radioactive test exceeded 99%. Retention during large-scale ISV operations is predicted to equal or exceed the pilot-scale performance because the contaminants will normally be buried deeper, thus retaining even more radionuclides in the block. The retention values are based on the release of contaminants to the off gas and a confirmation analysis of the block. From these data, decontamination factors (DFs) were calculated. The higher the decontamination factor (the mass of an element in the soil divided by the mass

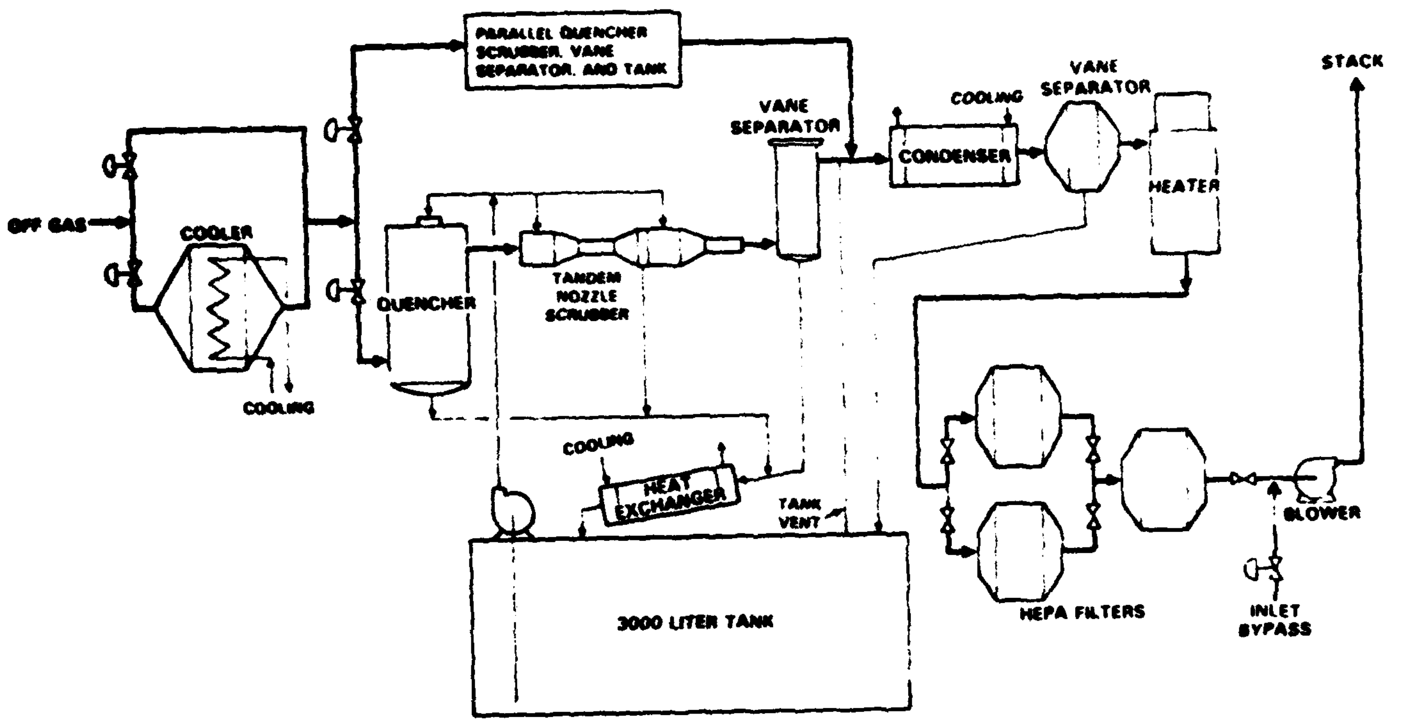

Figure 2. Schematic for the large-scale off-gas system.

released to the off-gas treatment system), the larger the amount retained in the vitrified block. Based on results from the pilot-scale system, soil-to-off-gas DFs for less volatile elements such as Pu, Sr, and U are expected to be 10^3 to 10^4 (99.9 to 99.99% retained). More volatile elements such as Cs and Sb should have DFs of 10^2 or greater (99% retained). Highly volatile heavy metals (Cd, Te, Zn, and Pb) should have DFs around 10^1 (90% retained). These values will vary depending on waste burial depth, the presence of a cold cap or resolidified surface glass, and the presence of gas generators within the melt zone. Element retention increases with burial depth, decreases with the presence of gas generators, and increases slightly with the presence of a cold cap. Decontamination factors for the off-gas treatment system (hood to stack) are as follows: for the semivolatiles and heavy metals (Cs, Cd, Pb, etc), 10^4, and for the less volatile nuclides (Sr and Pu), 10^5. Therefore, the overall process (soil-to-stack) DFs are 10^6 for the semivolatiles and 10^8 to 10^9 for less volatile materials. For particulates the DFs are about 10^{11}.

The ability of the waste form to retain the encapsulated or incorporated contaminants is of prime importance in determining the applicability of the ISV process. Vitrified soil blocks were analyzed to determine their chemical durability with a series of tests including 24 hour soxhlet leach tests. The bulk soxhlet leach rate for the product was less than 1×10^{-5} g/cm^2/day, an acceptable value. These rates were comparable to those of Pyrex® or granite, and much less than those of marble or bottle glass, as shown in Figure 3.

A 28 day Materials Characterization Center test (MCC-1) (Materials Characterization Center 1981) was also conducted on a contaminated soil sample that was vitrified in the laboratory at 1600°C. The overall leach rate of the vitrified soil was comparable to the 76-68 glass (a reference high level waste glass) and other TRU waste forms (Ross et al. 1982).

Another indication of the durability of the ISV waste form is found in a study of the weathering of obsidian, a glasslike material physically and chemically similar to the ISV waste form (Ewing and Hoaker 1979). In the natural environment, obsidian has a hydration rate constant of 1 to 20 μm^2 per 1000 years (Laursen and Lanford 1978). A value of 10 μm^2 per 1000 years, assuming a linear hydration rate, yields a conservative estimate of a 1 mm hydrated depth for the ISV waste form over a 10,000 year time span. Since hydration is the initial mechanism of weathering, the ISV block is expected to maintain its integrity at least through this 10,000 year time period.

Another important factor to consider in the waste form evaluation is the migration of the radionuclides once they are a part of the molten waste form. In the pilot-scale field tests, the radionuclides and heavy metals did not move beyond the vitrified block. Furthermore, analysis of the blocks from the tests revealed that the retained contaminants did not concentrate in the block, but instead were uniformly distributed, indicating extensive convective mixing during operation.

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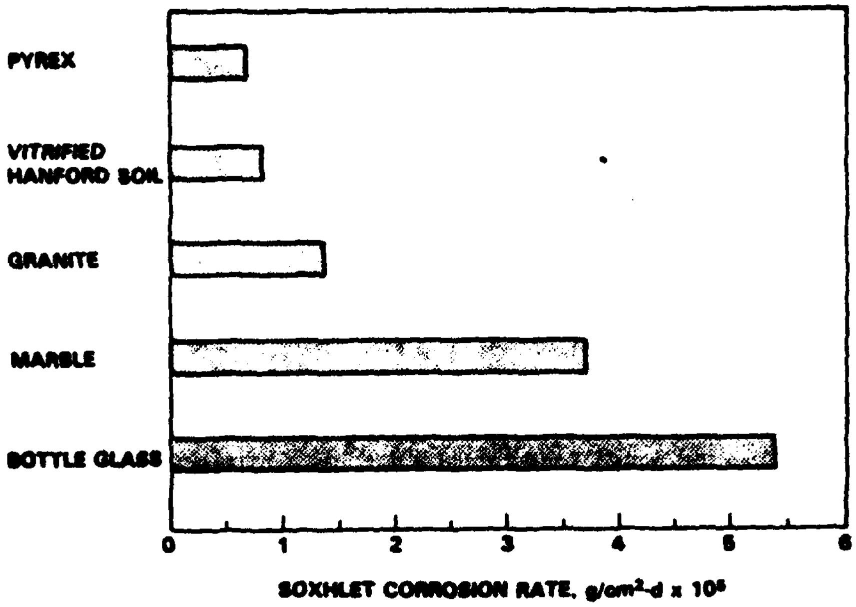

Figure 3. Leach resistance comparison of selected materials.

PROCESS PARAMETERS

PNL studied the effects of soil properties such as chemical composition, thermal conductivity, fusion temperature, specific heat, electrical conductivity, viscosity, and bulk density on nine soils from waste sites across the U.S. None of the variations in properties among the soils significantly impacted ISV operation. While soil moisture does affect the ISV process by increasing the power requirements and run time, it is not a barrier to its use (excluding aquifer sites with highly permeable soils). Soil moisture is an economic penalty, not a process impediment.

A mathematical model was devised to predict the behavior of the ISV system for waste sites with differing geometries and to assist in scale-up to the large-scale system without the need for extensive field testing. The effects on process performance of changes in soil properties, power system capability, and waste site geometry were evaluated using the model. Information produced included energy consumption, mass vitrified, operating time, melt depth, and melt width for various ISV configurations. The model was also used to determine the effect of soil moisture on the ISV process. To assess the effectiveness of the model as a predictive tool, model predictions were compared to results from the pilot-scale field tests. The predicted and actual values were very close, with usually less than 10% variance.

The effects on the ISV process of buried metals, cements, ceramics, combustibles, sealed containers, and explosives have been analyzed (Oma et al. 1983). Criticality limitations were also addressed. Both mathematical modeling and engineering-scale testing predict that the effects of metal inclusions will be insignificant unless a full short circuit is approached. During testing, the metal limit was not reached; however, a metal inclusion, accounting for 5% of the final block weight and occupying 70% of the distance between electrodes, was successfully vitrified.

In situ vitrification of soils containing concrete or pure cement inclusions decreases electrical conductivity of the melt zone and adds water vapor to the off-gas system. The flexibility designed into the large-scale power system compensates for any conductivity change resulting from vitrification of concrete or cement. With a design capacity of 104 std m^3/min, the large-scale off-gas system will handle water vapor and air inleakage generated during vitrification of pure cement. Nonmetallic ceramic materials that do not completely melt or dissolve during vitrification are effectively encapsulated by the glass and do not present a problem.

Buried combustible wastes pyrolyze, move to the melt surface, and burn during the ISV process. This increases both gas volume and heat load to the off-gas system. The large-scale off-gas system capacity will allow vitrification of a variety of waste configurations. Calculations show that combustible packages up to 0.9 m^3 and void volumes up to 4.3 m^3 can be processed without loss of hood vacuum. If combustibles are distributed relatively evenly throughout the soil, the off-gas system is capable of handling gases from soil containing 3200 kg of combustibles per meter of depth. This capacity includes air added to the hood to maintain 20% excess combustion air and assumes that the peak combustion rate is twice the average. Sealed containers can rapidly release gas during processing. Future study will include collection of confirmative empirical data related to sealed container releases; however, the maximum postulated gas release is expected to be within the capacity of the large-scale off-gas system.

Soil containing up to 25 wt% TNT and/or RDX can be incinerated safely as long as the mixture is not contained (Kirshenbaum 1982). Although soils of this nature are not present at Hanford, explosive wastes have been disposed in soil at other sites, which may consider ISV as a stabilization option.

The potential for criticality due to the presence of fissionable materials has been addressed. The ISV system can effectively process soils containing a Pu areal limit of less than 1 kg Pu per square meter. Sites containing Pu levels approaching or surpassing this point should consider exhumation and recovery treatment prior to ISV as a stabilization option.

ECONOMIC ANALYSIS

The cost of using ISV as an in-place stabilization technique was estimated for radioactively contaminated soils.

The components that contribute to the basic cost of ISV are site preparation activities, annual equipment charges, operational costs such as labor, and consumable supplies such as electricity and electrodes. Employing the large-scale system, five different configurations for TRU contaminated soil sites were evaluated using the four basic cost-contributing categories. The results are provided in Table 1.

When using the cost figures in Table 1, it is recommended that ranges be employed for making cost estimates. For example, to estimate the cost of selectively vitrifying portions (a volume of 2900 m^3) of a waste site at Hanford, as shown in Figure 4, the lower boundary of the range should be case 3 (local power, above average manpower, average heat losses): \$138/m^3, for a total cost of 2900 m^3 x \$138/m^3, or \$400,200 or \$400 K. The upper boundary of the range should be a combination of cases 1, 2, and 3 (local power, above average manpower, and high heat losses), which calculates to be 2900 m^3 x \$138/m^3 x [ratio of heat loss effects: 142 (case 1)/116 (case 2)] = \$489,900, or \$490 K.

TABLE 1. COST ESTIMATES FOR FIVE ISV LARGE-SCALE CONFIGURATIONS

Number	Site	Power	Heat Loss	Manpower Level	Total Cost of Soil Vitrified, 1982 \$/m^3
1	Hanford	Local	High	Average	142
2	Hanford	Local	Average	Average	116
3	Hanford	Local	Average	Above Avg.	138
4	Generic	Local	Average	Average	135
5	Generic	Portable	Average	Average	179

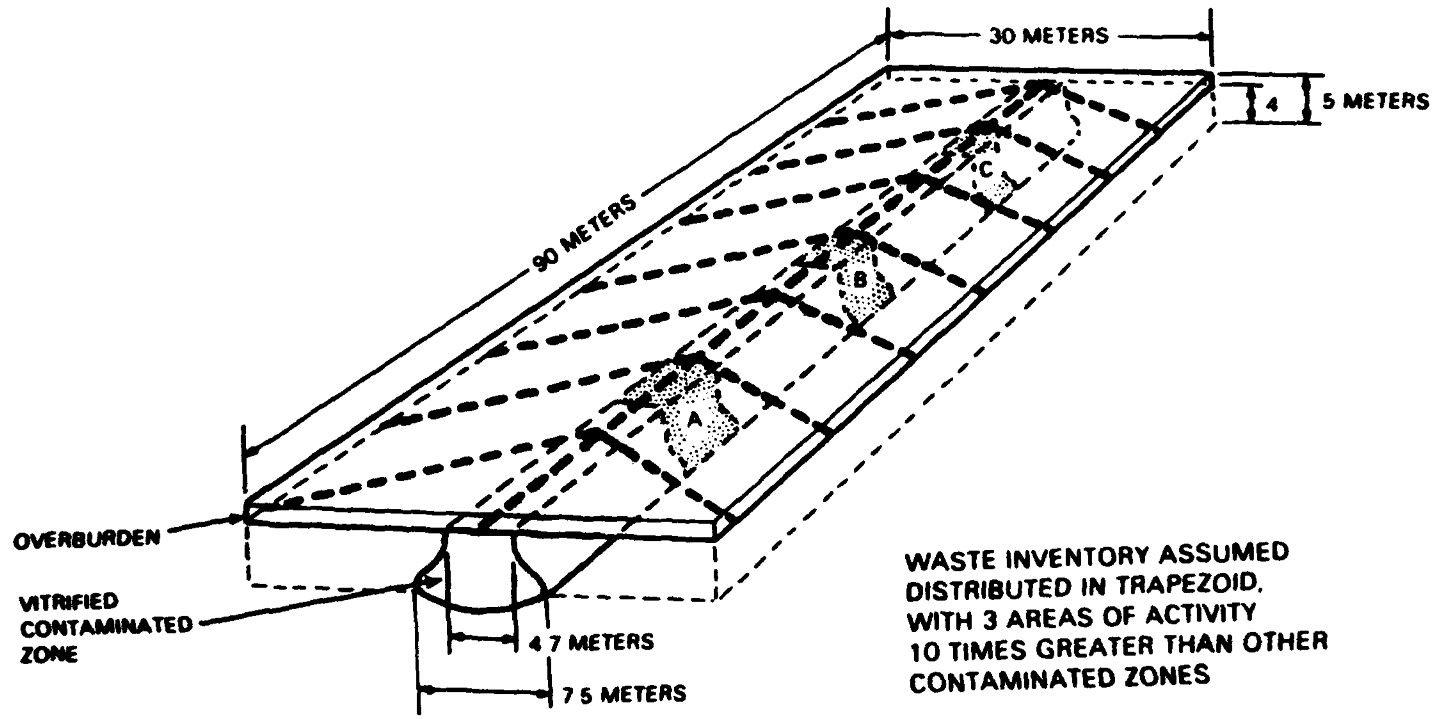

Figure 4. Waste distribution in a 90 x 4 x 4 m site.

ASSESSMENT OF WASTE SITE APPLICATIONS

Preliminary studies (Kennedy et al. 1982; Oma et al. 1983) indicate that a combination of selective vitrification and appropriately scaled barriers may be the most cost effective in-place stabilization technique for those Hanford TRU sites requiring remedial action. This approach is consistent with the findings of the National Academy of Sciences (National Academy of Sciences 1978), which stated that retrieval of buried TRU waste for disposal in a geologic repository could be more hazardous then disposing the waste in place. This approach is also recognized in the Long-Range Master Plan for Defense Transuranic Waste Management (U.S. Department of Energy 1983), which states that "deep geologic disposal may not be the most economical means of safe disposal for all TRU wastes." DOE Order 5820.1 (U.S. Department of Energy 1982) allows field organizations to establish new or alternative TRU waste management practices. In situ vitrification is one of the engineered permanent disposal alternatives being examined to meet these needs.

Application of ISV to hazardous chemical waste sites requires further evaluation and testing to determine the thermal effects of ISV processing on typical chemicals. In situ vitrification has been shown to be effective on heavy metal contaminants and some organic constituents (tributylphosphate and dichlorobenzene); however, additional testing and investigation could insure a beneficial application of ISV to a variety of waste sites.

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APPLYING AN INNOVATIVE APPROACH TO FIELD INVESTIGATIONS AT A REMEDIAL ACTION SITE

Michael F. Coia and Michael H. Corbin[1]

INTRODUCTION

Typical field investigation programs have utilized soil borings and groundwater monitoring wells to characterize contamination at hazardous waste sites. This paper describes an approach that can be applied at a hazardous waste site where known groundwater contamination exists and remedial action is necessary to mitigate the environmental concerns. The sampling program is conducted to locate, as accurately as possible, the position, extent and depth of contaminant source areas, and to identify the potential contaminants present as well as the potential extent of contaminant migration in the soil and groundwater. These sampling procedures utilize the maximum number of backhoe trench excavations (to locate the apparent boundary of contaminant source areas and obtain composite soil samples along a prescribed coordinate grid system) and field-implemented analytical techniques (to screen soil samples and eliminate those of little or no contamination). Laboratory analytical procedures are used to characterize the waste constituents found in the source areas and contaminated soils, and to provide the necessary level of quality assurance. In all, the sampling program described herein maximizes the use of field-implemented analytical techniques which reduces the overall cost of laboratory analytical procedures.

To perform a field investigations program which describes potential contaminant source areas, the following general sampling methodology should be incorporated:

a. Establish a coordinate grid system over the entire area of potential concern. A 50-foot center grid system should be established over the areas identified as probable source areas, and a 100-foot center system should be satisfactory over the remaining areas.

b. Perform a topographic survey over the site area to accurately locate the position and elevations of roads, buildings, and site features. Establish elevation control based upon USGS datum, and tie the topographic survey into the established grid system to produce a topographic map for the areas of concern.

[1]Michael Coia is an Associate Project Engineer with Roy F. Weston, Inc.
Michael Corbin is Section Leader of the Solid and Hazardous Waste Management Group at Roy F. Weston, Inc.

c. Conduct a program of surface and subsurface waste, groundwater and soil investigations to assess the potential contaminant sources in the identified areas. The program of visual observations, soil trench excavations, waste borings, soil borings, field analytical sampling, and laboratory analytical sampling is discussed in the following paragraphs.

TOPOGRAPHIC SURVEY

The initial phase of the sampling program should consist of the establishment of a coordinate grid system and the performance of a topographic survey over the contaminant areas of concern. The intent is to establish location and elevation control at the site, which aids in conducting the sampling activities. The following activities would be incorporated into the topographic survey phase:

a. A survey crew or a subcontractor would lay out the coordinate grid system and perform the topographic survey.

b. Grid points would be staked with lath (or equivalent) and labeled with north/south and east/west coordinates for identification.

c. State Planar System (or equivalent) coordinates would be used as the basis for this grid system. The surveyor would be responsible for identifying the grid points and tying the detailed grid system into these points.

d. A topographic survey would be performed over the designated areas to locate the elevations and locations of the following. A 2-foot elevation contour interval should be used.

- Any railroad tracks
- Site access roads (paved and gravel)
- Site boundaries
- Fence locations
- Natural drainage ditches and drainage pipes
- Site utility lines (water and power lines)
- Site features

e. Elevation control would be established based upon the nearest USGS datum or existing bench marks and establish any additional bench marks as necessary to complete site work activities.

f. All surveying instruments would be calibrated in accordance with state regulations prior to the start of work. All stadia distance measurements should be accurate to within 0.01 foot per 100-foot length, and all elevation measurements should be accurate to within 0.1 foot.

SITE MOBILIZATION/PRE-SAMPLING ACTIVITIES

Pre-sample activities refer to the site mobilization operations which are carried out in support of the field sampling efforts at a hazardous waste site. In many ways the pre-sample activities are critical to the optimum functioning of the field investigations program. The following operations should be accomplished as part of the site mobilization/pre-sampling activities:

a. Develop the Sampling Plan which outlines the number and locations of sampling points. This would describe the facilities required at the site, the level of personnel safety required, the types and number of sample containers and the daily operation of sampling activities.

b. Arrange for the procurement of the following sitework requirements (in the office prior to initiating any sitework activities)

   - Security measures (guards & security fences as necessary)
   - Command trailer equipped with the necessary amenities to support field work
   - Phone service
   - Electric tie-in or portable electric generator
   - Potable water source (if necessary)
   - Portable chemical equipment
   - Air monitoring equipment
   - Decontamination area for personnel decon procedures

c. Delineate the "Clean Areas" at the site where the command trailer and decontamination facility are to be placed. Set up the boundary fence (or roped off area) between the sitework and clean areas, and tie in the necessary utilities to the command trailer.

SAMPLING OF CONTAMINANT SOURCE AREAS

The field sampling program should incorporate backhoe excavations and auger-drilled soil and waste borings. These general field approaches would satisfy the overall sampling objectives of locating and evaluating the potential contaminant source areas. During the sampling operations at a potential hazardous waste site, samples of waste, soil and groundwater (if appropriate) should be collected. The following sampling types are discussed herein (the listing order does not represent any reference to chronologic order):

a. Soil trenching samples. Composite grab samples from the trenching operations should be collected from the excavated soil piles.

b. Waste corings. Composite core samples should be collected from the waste material along the waste boring profile.

c. Soil corings. Core samples of the soil should be collected from the soil borings at designated depths along the profile in contaminated and presumed uncontaminated areas.

d. Groundwater samples. Samples of the subsurface groundwater should be collected within the well point monitoring locations if these samples help to characterize the contaminant source areas.

Soil Trenching Operations

The use of soil trench excavations is becoming an established field sampling method to verify the locations of the disposal areas and to identify any additional areas of soil contamination. Established backhoe and trenching techniques can be used to excavate the sampling pits through the soil layers adjacent to the disposal areas and along the established grid system. If at all possible, excavation through the waste material itself should be avoided. A mobile sample port of a field-operated organic vapor analyzer can be utilized to "sniff" the surface of the excavated trenches to establish variation in the concentrations of organic compounds. This data can be utilized to indicate the location of the concentrated waste materials. Once the disposal area or waste material is encountered, the trench excavation should be terminated, since the contaminated boundary would be located.

A commercially available, non-tracked backhoe capable of excavating soil to depths up to 20 feet should be used during the trenching operations to locate the boundaries of contaminant source areas. Once the locations of the soil trenches are identified,the backhoe would excavate soil to accomplish two distinct sampling objectives. These include:

a. Trench along a prescribed path to locate the boundaries of the potential contaminant source areas. These trenching operations should begin approximately 50 feet from the waste area and proceed within uncontaminated soils toward the waste piles. Some of these trenches (at field-determined locations) can be continued through the waste disposal areas to help identify waste profiles and boundaries.

b. Trench shallow sampling pits at the designated 100-foot center grid points along the coordinate system to identify any gross contamination within the soils beyond the identified areas of concern. These trench pits can be used to eliminate the placement of shallow borings at a reduced overall cost.

Continuous air monitoring would be conducted at the trench paths and shallow trench pits using either the Miran Infrared Analyzer (Miran/IR) or a portable organic vapor analyzer (OVA) unit. Personnel safety precautions would be taken to protect sampling personnel from the potentially hazardous vapors that may be generated during trenching excavations. The backhoe operator and sampling personnel would be equipped with air purifying cartridge respirators to be used if the air monitoring results indicate a potential concern. Detailed personnel safety precautions should be outlined in a Safety Plan for any sitework activities.

Trenching operations may be conducted within the waste piles or within highly contaminated soils. Once the waste disposal area is encountered by the trench paths, or if analytical screening results indicate organic concentrations in excess of background levels within the shallow trench pits, the trenching operations would be ended. Also, trenching operations would be curtailed if groundwater within the site soils is a prohibitive concern. Excavations should be made down to a depth of between 5-10 feet within the trench paths and shallow trench pits. Excavations may be made deeper along the trench paths, adjacent to a disposal area, if location of the disposal trench bottom is required. The trench path excavations should not be used exclusively to map the disposal trench bottom, since soil borings will provide this data. Backfill of the trenches should be performed immediately following sampling at a particular location, and compaction of the trenches should be performed in layers to the maximum achievable degree using the backhoe.

Figure 1 illustrates a typical sampling approach from backhoe trench excavations. All soil samples collected from the trenching operations should be representative composite samples. No sampling would be performed from within the trench or pit itself, instead composite samples would be collected from the excavated soil pile adjacent to the trench. At no time should any sampling personnel be permitted to enter any excavated trench or pit area. Samples should be collected in the following manner:

a. From the trenches, a sample should be collected approximately every 10 feet until the contaminated waste disposal area is encountered. Within the shallow trench pit, one discrete sample would be collected. (Wherever possible, shallow trench pits would be excavated following completion of other soil and waste sampling activities.)

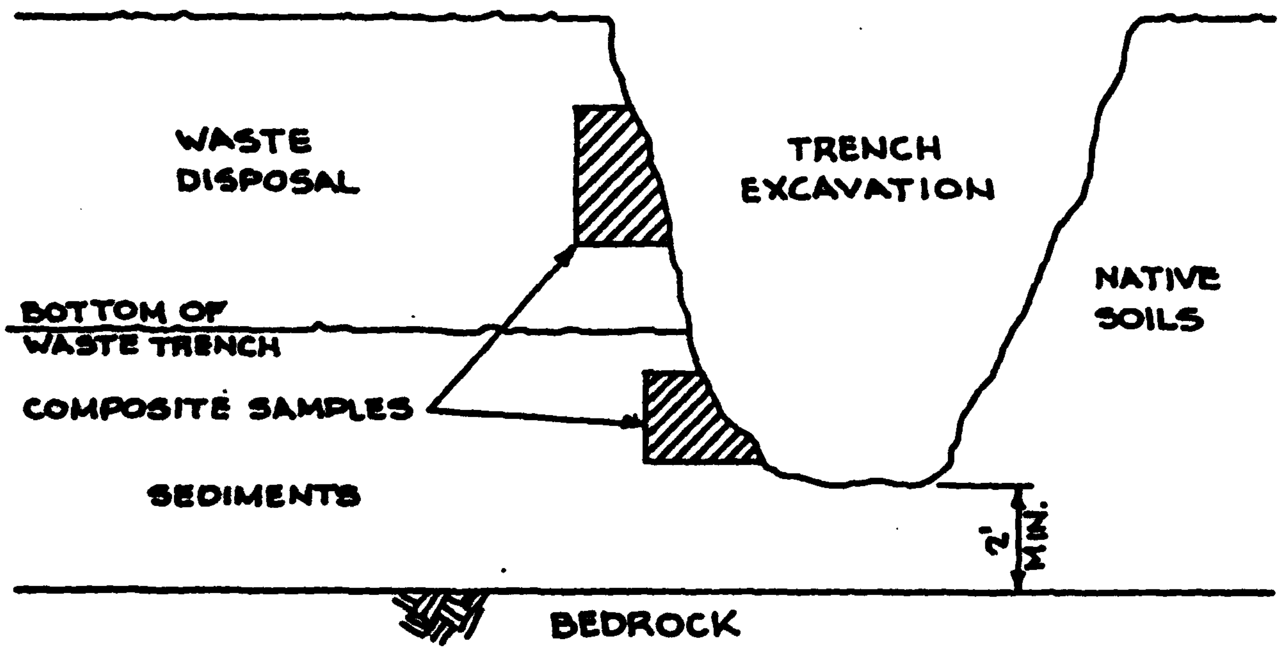

FIGURE 1 TYPICAL SKETCH OF TRENCH EXCAVATIONS AND SOIL SAMPLING

b. Excavations at the sampling location should be made down to a depth of 5 feet. The specific backhoe bucket load for the sample should not be dumped on the ground. A hand auger (cylindrical bucket-type) would be used to collect one composite sample from three representative locations from within the interior of the bucket load. These samples would be field analysed/screened using the Miran/IR unit.

c. Additional samples may be placed in glass jars with self-sealing screw-type lids, labeled, and temporarily stored in individual compartments of sectioned cardboard boxes.

d. If the waste pile is encountered by the trench, or if trench air monitoring or the field analytical results indicate high concentrations of target contaminants above background levels, duplicate samples of the soil may be sent to the laboratory for analysis. If these samples are sent, the protocols for hazardous waste sample packaging and shipment would be followed.

Soil and Waste Boring Operations

The results of the soil trenching operations would identify the lateral extent or boundaries of site contamination at each of the potential source areas of concern. A detailed soil boring program would then be initiated within and adjacent to the identified contaminated areas. These soil and waste borings would be used to describe soil types and the extent of contamination within the soil profile with depth. Hollow stemmed augers would be used to drill the soil and waste borings down to the depth of, but not extending into, bedrock at the prescribed locations. The truck-mounted drilling equipment would incorporate 6-inch ID augers, so that the well point screens and casings can be set inside the hollow stems (if appropriate). Figure 2 presents a sketch of a typical sample collection approach for soil and waste borings.

During the process of drilling the waste and soil borings at the sites, relatively undisturbed soil samples would be collected with a standard 2-inch split-spoon sampler. The samples would be collected continuously through the hollow stem augers as drilling progresses down to bedrock. All samples should be examined and described by the Field Geologist in accordance with prescribed standardised protocols. The geologist would describe and classify the samples based upon their general classification, color, texture, estimated water content, and depth from land surface. Detailed boring logs would be developed for each of the waste and soil borings. The descriptive parameters discussed herein would be included on the boring logs. Depths should

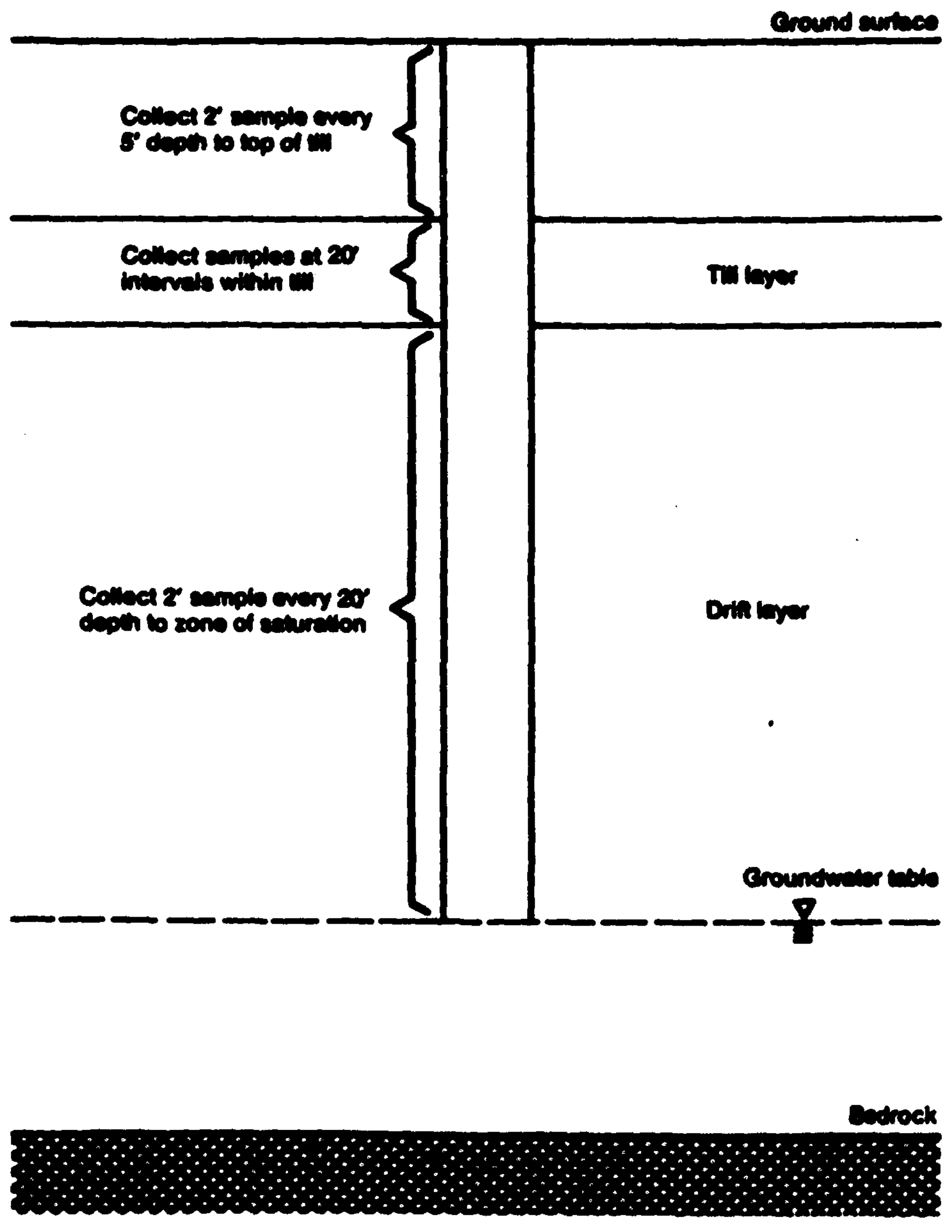

FIGURE 2 TYPICAL SOIL BORING
SAMPLE COLLECTION

be recorded for the samples in feet and decimal fractions thereof. Soil descriptions should be in accordance with the Unified Soil Classification System (USCS). Soil samples would be fully described on the log. The data (descriptive parameters) in the sampling log would include the following:

a. Site identification and location coordinate (using alphanumeric boring code and grid system coordinate).

b. Percent recovery (P.R.) of samples.

$$P.R. = \frac{\text{length of core sampling recovered}}{\text{length of interval sampled}}$$

c. General soil classification (such as "sandy clay") and USCS symbol (such as "CL").

d. Munsell soil color numbers (give both narrative and numeric color description).

e. Plasticity.

f. Consistency (for cohesive soils) and density (for non-cohesive soils).

g. Field moisture.

h. Texture/fabric/bedding.

i. Depositional environment/lithological boundaries.

j. Depth of first-encountered water and static elevation (changes in water level three successive days after completion).

k. Total interval drilled.

l. If a well point is placed, construction features such as grouting, gravel pack, screen and casing interval, bentonite, depths, etc.

m. Time delays or problems encountered, including loss of core, loss of interval, drilling rig problems, etc.

Representative soil samples from each split-spoon should be placed in glass jars with self-sealing screw type lids, labeled, and temporarily stored on-site. Each sample container would be labeled in accordance with the prescribed sample packaging and shipment protocols. Collected samples for analysis would be secured in a sample storage chest following chain-of-custody procedures. The prescribed samples will either be analysed on-site or sent to an analytical laboratory.

Analytical and spatial information resulting from the sampling and analytical program should be utilized as input to an isopleth analysis and contour plotting routine (an example is CPS-1). This routine can compute iso-concentration contours for the target contaminants and plot the isopleths on a map of the study area. Deposits of target contaminants other than those already identified would be delineated. If significant new deposits of target contaminants are identified along the grid pattern beyond the limits of the source areas, these locations may be resampled using soil boring techniques described previously. Isopleth maps such as these can be used to delineate the contaminant source areas which require remedial action. Excavation and treatment volumes can be readily calculated and utilized in a remedial action evaluation.

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TREATMENT OF WASTEWATER (RED WATER) RESULTING FROM TNT PURIFICATION

J. CARRAZZA & E. PREGUN
U.S. ARMY ARMAMENT RESEARCH AND DEVELOPMENT CENTER
DOVER, NJ 07801

AND

C. CHANDLER & W. HELBERT
HERCULES INC., RADFORD ARMY AMMUNITION PLANT
RADFORD, VA 24141

"Red Water is the product which results from the Sellite process which has been used, since World War I, for the purification of trinitrotoluene (TNT) in the United States. Sellite (sodium sulfite) reacts preferentially with the undesirable meta-TNT isomer in crude TNT to produce water soluble sodium dinitrotoluene sulfonate. This solution (red water) also contains 2,4,6-TNT plus various oxidation products and may contain 20-25% solids. In the past, disposal was accomplished by incineration, leaving a sulfate ash, or the red water was concentrated and taken by the paper industry for make-up sodium-sulfur value. Both methods are considered undesirable for reasons of economics, lack of availability of landfill sites, pollution abatement, and reliability.

Numerous approaches have been investigated to either concentrate the red water for disposal or recover reusable products. These approaches included reverse osmosis, acidification, Tampella Process, Atomics International Aqueous Carbonate Process, SCA Billerud Process, and the Sonoco Sulfite Recovery Process (SSRP). An assessment of these techniques based upon level of TNT production, foreign patent and scale down problems, simplicity of design, capital and operating cost estimates and other criteria resulted in selection of the SSRP for further evaluation,

Extensive laboratory and pilot plant studies of process feedstock formulations, pellet versus slurry feed, multi-hearth versus rotary kiln furnace, evaporators, separators, dryers, feedstock mixers and transport systems were conducted. This resulted in the development of criteria currently being utilized for implementation of a sulfite recovery facility to support TNT production at Radford Army Ammunition Plant (RAAP). The SRP process as developed for RAAP is described as follows.

Red water (15% solids) flows from TNT purification into storage tanks. The pH is then adjusted to 6.5-7.0 to minimize foaming during concentration. It is then concentrated to 35% solids in a multiple-effects evaporator (MEE) and then mixed with filter cake in the repulper section of a belt filter. The resultant repulper mix is pumped into a hollow shaft evaporator for further concentration to 68% solids. Finally, recycled furnace ash and petroleum coke are added to achieve a solids concentration of 74%. This thick paste passes into a screw feeder which inserts it onto the top hearth of the multiple-hearth furnace (MHF).

The MHF consists of 8 hearths and a rabble shaft assembly for stirring and advancing the solids to the drop holes leading to the next hearth below. The RAAP furnace will have 6 hearths devoted to separating the sodium and sulfur in the red water portion of the feedstock. These hearths will be operated at 950°C (1750°F) with a reducing atmosphere. In the MHF sodium combines with aluminum in the filter cake and forms sodium aluminate ($NaAlO_2$) which is retained in the ash. Simultaneously, the sulfur in the feedstock is converted to sulfur dioxide (SO_2) and hydrogen sulfide (H_2S) which exits the furnace in the flue gas stream. The ash contains sodium sulfide (Na_2S), a hazardous impurity, and it is, therefore, passed downward through the seventh and eighth hearths where it is oxidized to sodium sulfate (Na_2SO_4), a harmless impurity in the finished Sellite solution.

Hot oxidized ash at 820°C (1500°F), nominal, from the MHF passes through a cooler and is then ground and mixed with water to form a slurry used to create sodium sulfite (Na_2SO_3) in the precipitator.

The flue gas which contains H_2S and carbon monoxide (CO) is passed through an afterburner where both the H_2S and CO are oxidized. The resultant SO_2 concentration in the flue gas is 6000 ppm. This gas stream passes through a waste-heat recovery boiler where it is cooled and energy is recovered as steam. The exiting flue gas is cooled to 74°C (165°F), the optimum temperature for efficient scrubbing of SO_2.

SO_2 is removed from the gas stream in a Schnieble absorber using Na_2SO_3 solution as the scrubbing medium. The product of this operation is sodium bisulfite ($NaHSO_3$) solution.

$NaHSO_3$ solution from the absorber is mixed with ash slurry to produce a slurry of Na_2SO_3 solution and $Al(OH)_3$ precipitate. This slurry is passed through a solid-bowl centrifuge which separates the sludge from the Na_2SO_3 solution. Part of this solution is returned to the absorber where is captures SO_2 from the flue gas stream. The balance of the Na_2SO_3 solution plus the sludge passes to a belt filter for separation. The cake from the belt filter returns to the MHF via the repulper mix. The Na_2SO_3 solution goes into a tank-type clarifier where finely divided suspended solids are removed. The clarified Sellite goes to storage for reuse in TNT purification, where it will be converted back into red water as it purifies crude TNT to produce alpha-TNT, the desired product of TNT manufacture.

U.S. ARMY
ARDC

US ARMY ARMAMENT RESEARCH
AND DEVELOPMENT CENTER
DOVER, NEW JERSEY

LARGE CALIBER WEAPON SYSTEMS LABORATORY

PRINCIPAL INVESTIGATORS

HERCULES INC. — RADFORD ARMY AMMUNITION PLANT

- DR. CARL CHANDLER
- MR. WILLIAM HELBERT

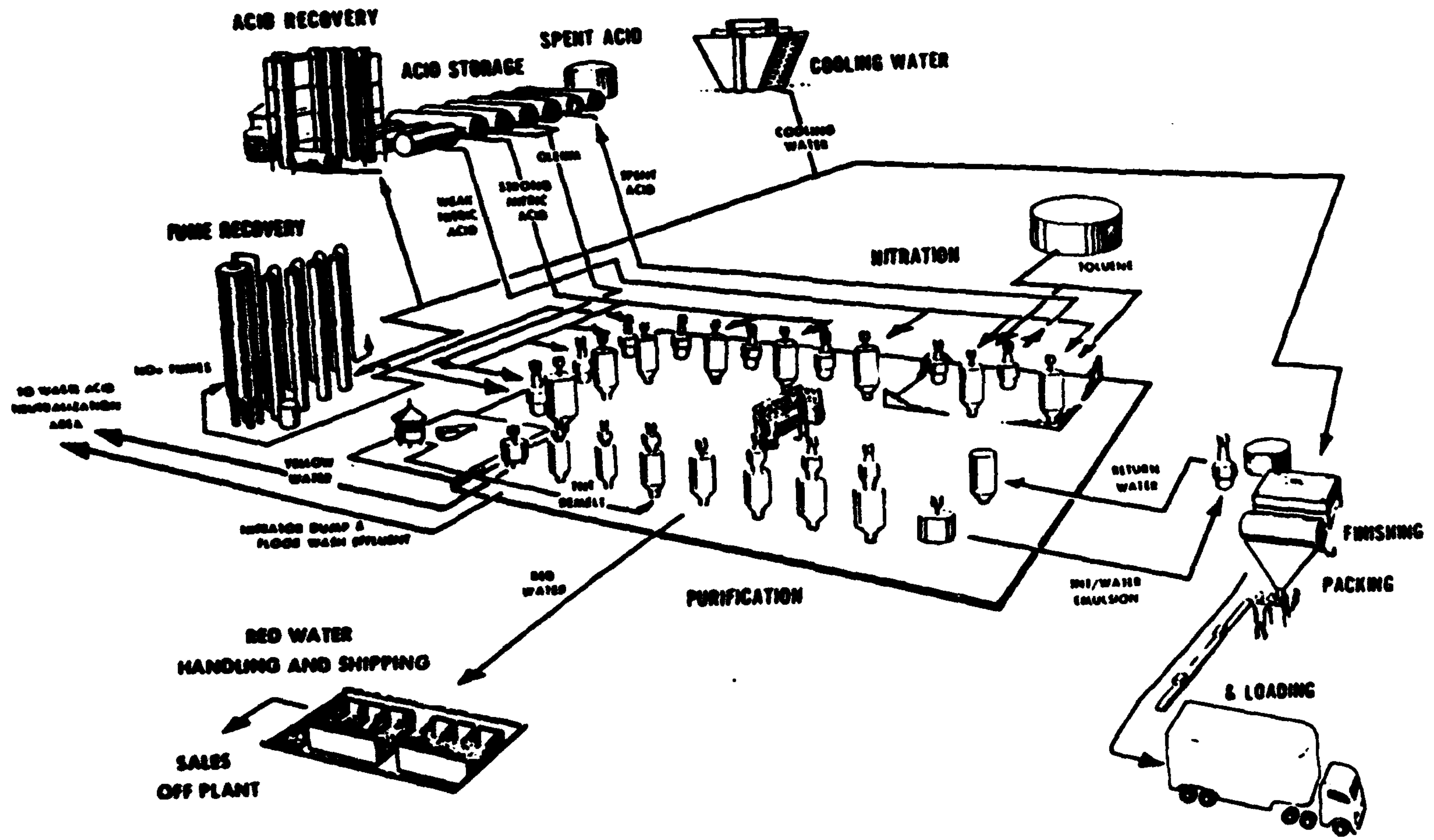
ICI AMERICAS INC. — VOLUNTEER ARMY AMMUNITION PLANT

- MR. EDWARD BINGHAM

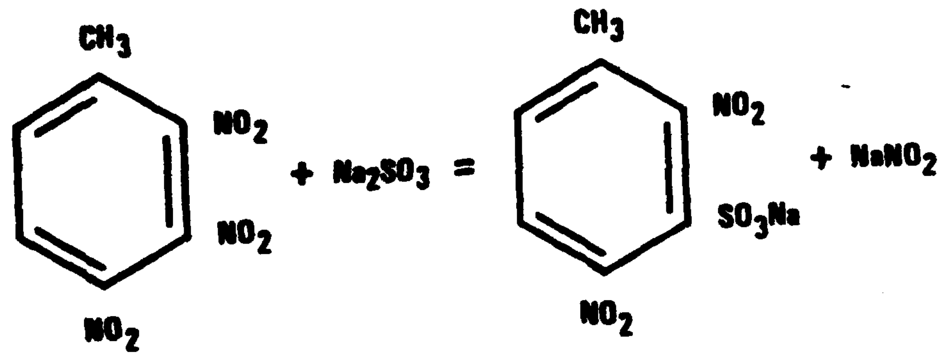
US ARMY ARMAMENT RESEARCH AND DEVELOPMENT CENTER

- MR. EDWARD PREGUN
- MR. JAMES CARRAZZA

TNT FACILITY AND SUPPORTING OPERATIONS



SELLITE PURIFICATION PROCESS



COMPOSITION OF RED WATER

WATER	74.6%
SODIUM NITRATE	1.7%
SODIUM SULFATE	0.6%
SODIUM SULFITE	2.3%
SODIUM NITRITE	3.5%
ORGANICS	17.3%

QUANTITY OF RED WATER AT MOBILIZATION

FACILITY (AAP)	TNT LINES	GAL PER DAY	R.W. SOLIDS LBS PER DAY
RADFORD	2C	7,700	30,800
VOLUNTEER	6C 5B	54,200	169,400
JOLIET	6C 10B	85,200	246,400
NEWPORT	5C	19,200	77,000

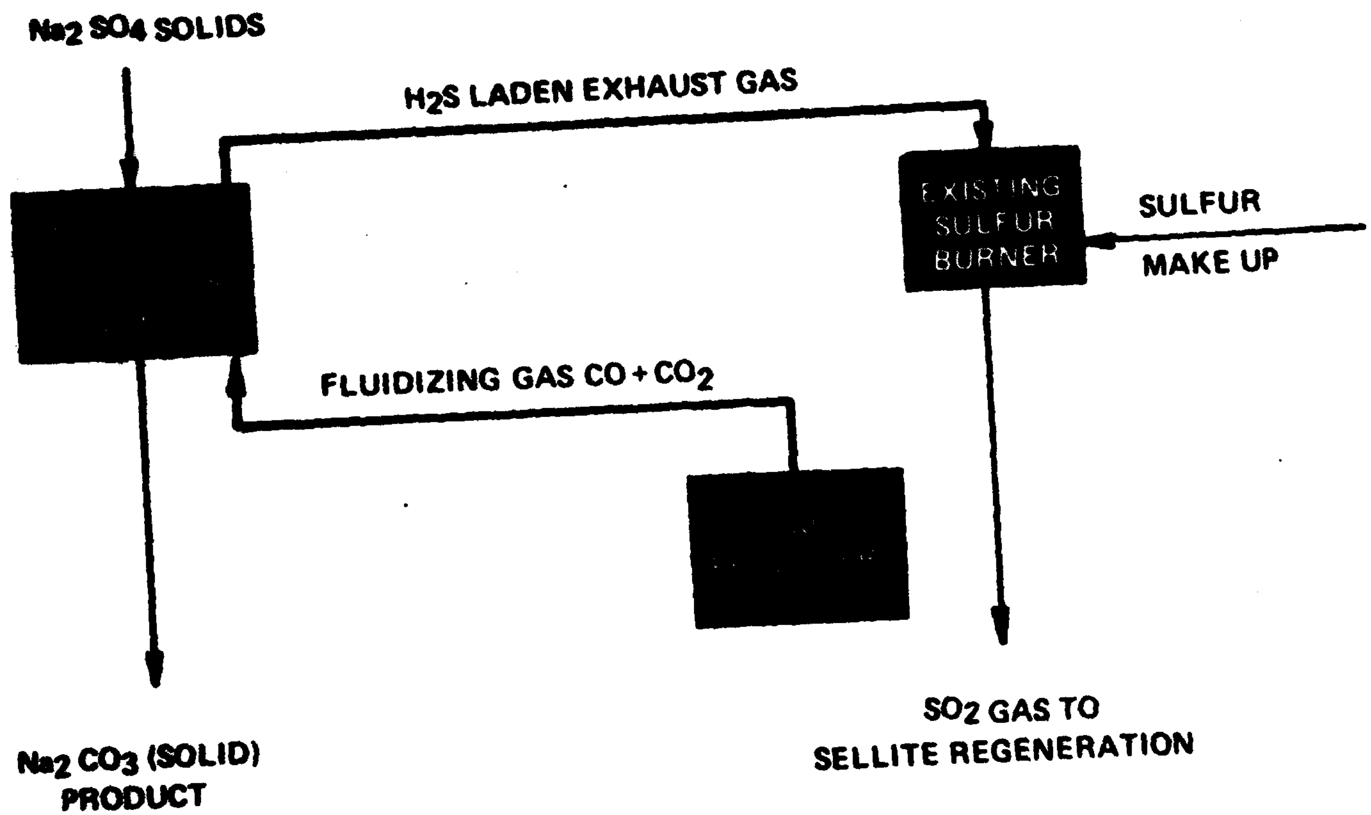
CURRENT METHOD FOR DISPOSAL

METHOD	DISADVANTAGES
INCINERATION AND LANDFILL	ECONOMICS ENERGY INTENSIVE SULFATE ASH LANDFILL SITES
DISPOSAL TO PAPER INDUSTRY	ECONOMICS DISAPPEARING MARKET SUPPLY UNDEPENDABLE PROCESS ADJUSTMENTS EPA REGULATIONS

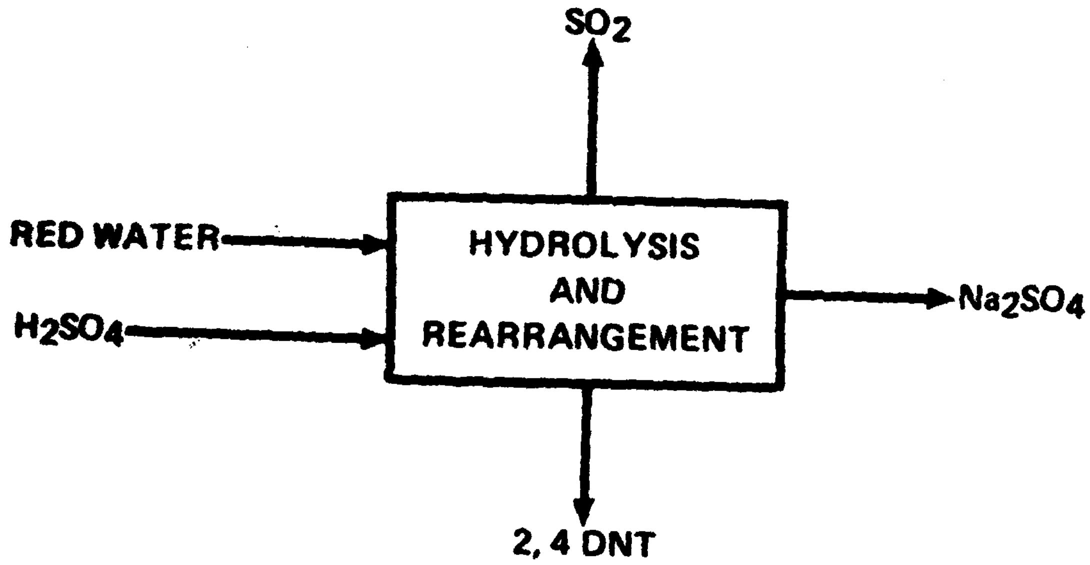
DISPOSAL OF RED WATER FROM TNT PURIFICATION

- REVERSE OSMOSIS
- FLUIDIZED BED
- TAMPELLA PROCESS
- ACIDIFICATION OF RED WATER

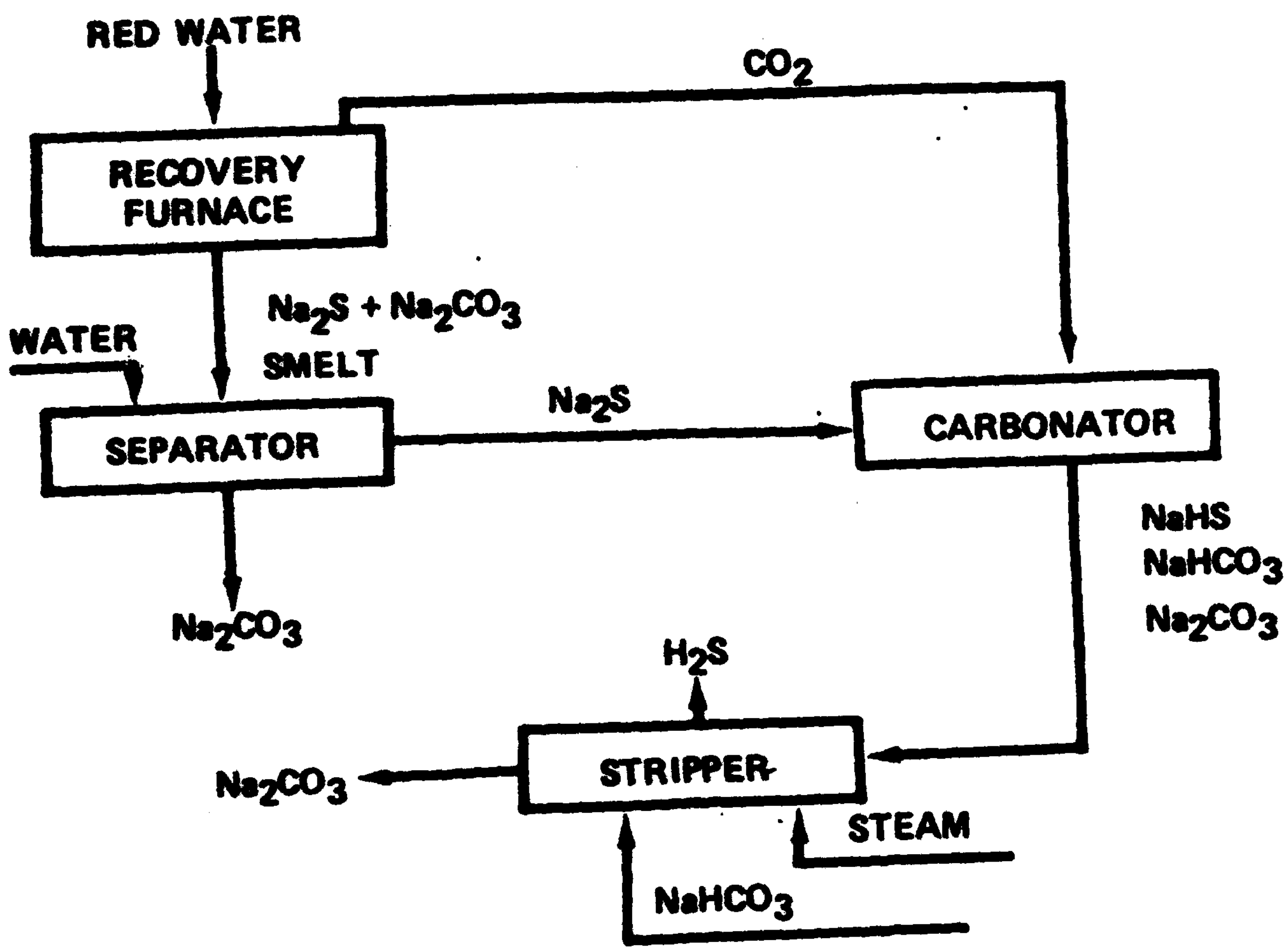
Na_2SO_4 FLUIDIZED BED REDUCTON SYSTEM



ACIDIFICATION OF RED WATER



TAMPELLA PROCESS



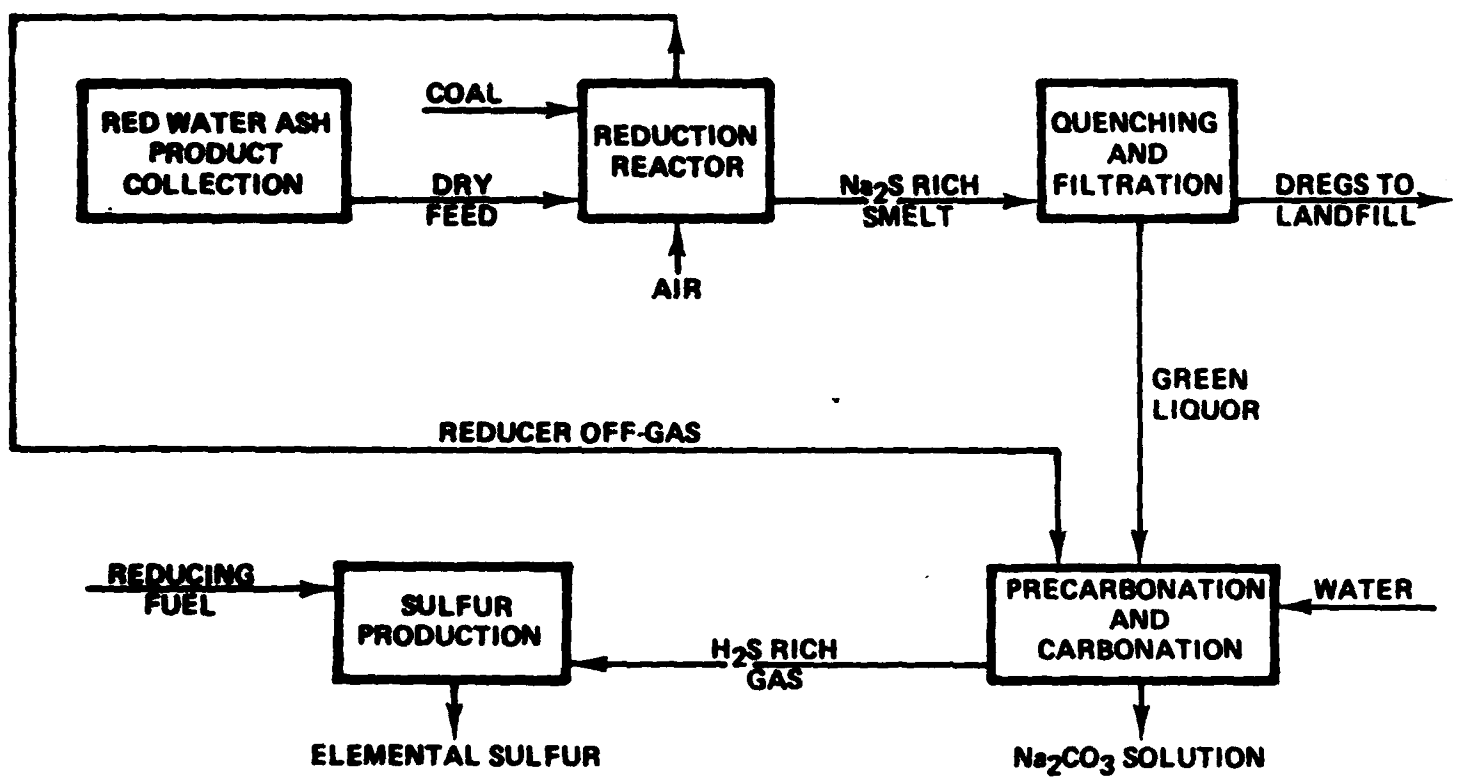
PROBLEM AREAS (TAMPEL)

FOREIGN PATENTS
SCALE DOWN
CAPITAL AND OPERATING COST

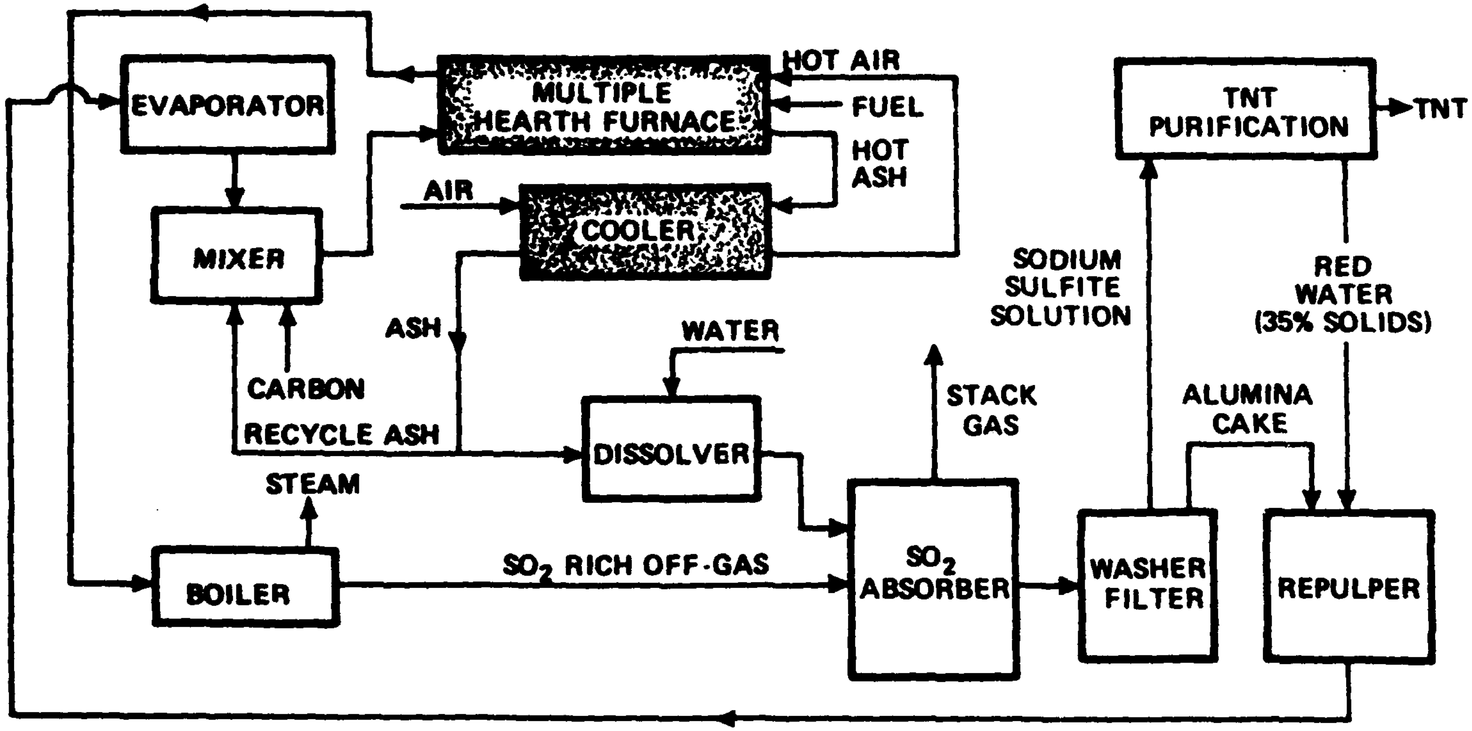
ALTERNATE RECOVERY PROCESSES

- ATOMICS INTERNATIONAL – AQUEOUS CARBONATE PROCESS (US)
  - AI – REDUCTION
  - B&W – REDUCTION
- SONOCO SULFITE RECOVERY PROCESS (US)
- SCA – BILLERUD RECOVERY PROCESS (FOREIGN)

AQUEOUS CARBONATE PROCESS



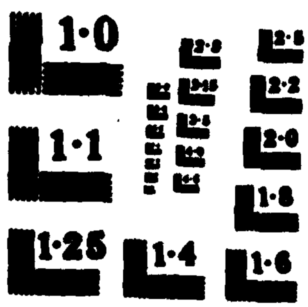
SONOCO SULFITE RECOVERY PROCESS



AD-A148 194 PROCEEDINGS OF THE ENVIRONMENTAL SYSTEMS SYMPOSIUM (13TH) HELD AT BETHESDA MARYLAND ON 20-22 MARCH 1984 (U) AMERICAN DEFENSE PREPAREDNESS ASSOCIATION ARLINGTON VA 22 MAR 84

3/4

UNCLASSIFIED F/G 13/2 NL


1·0
1·1
1·25
1·4
1·6
1·8
2·0
2·2
2·5

SONOCO SULFITE RECOVERY PROCESS

ADVANTAGES

- NO SMELT
- DIRECT REDUCTION TO SO_2
- NO SCALE DOWN PROBLEMS
- IMPROVED EFFICIENCY
- CAPITAL & OPERATING COST

DESIGN CONSIDERATION

1. FEEDSTOCK MIXER-PELLETIZER
2. FEEDSTOCK TRANSFER SYSTEM
3. FEEDSTOCK DRYER
4. KILN DESIGN- ROTARY VS MULTI-HEARTH
5. HEAT RECOVERY- FLUE GAS AND ASH
6. ASH COOLER DESIGN
7. DUST COLLECTION SYSTEM
8. SCRUBBERS

POLLUTION ABATEMENT PROBLEM AREAS

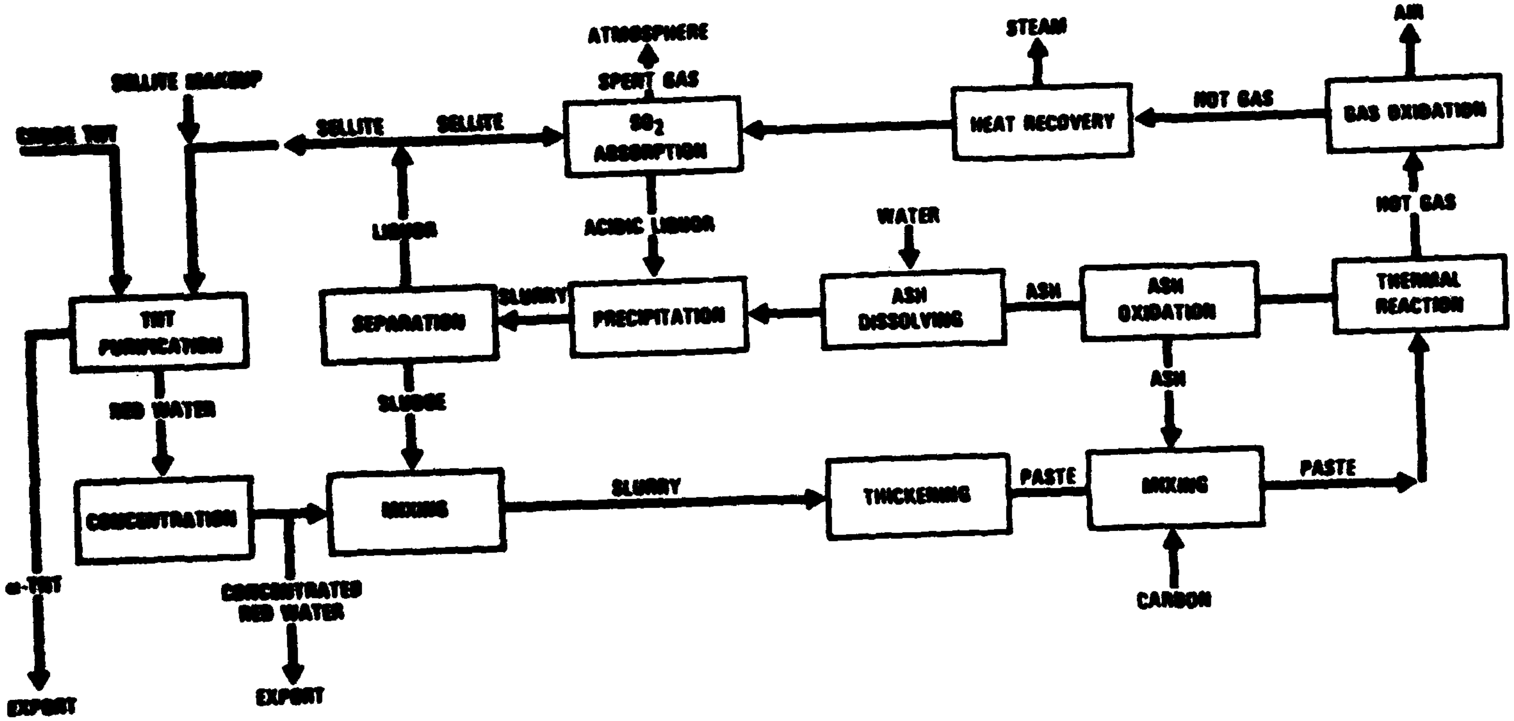
AIR

- SO_2 ABSORBER
- WET SCRUBBER
- ASH HANDLING
- PELLETIZER VS FEEDSTOCK MIXER

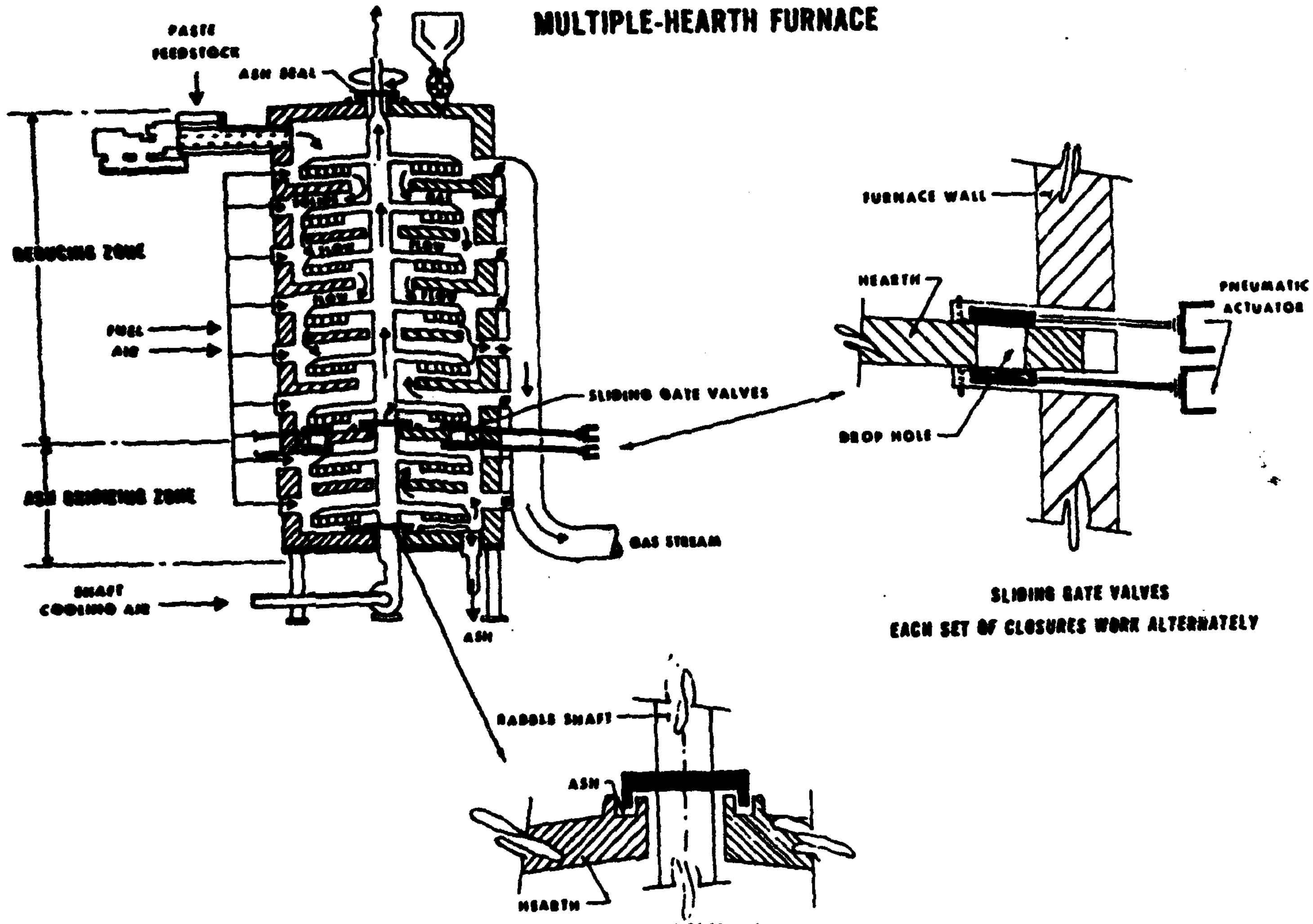
WATER

- PUMP LEAKAGE
- ASH w/RAIN
- SPILLS

RAAP SULFITE RECOVERY PROCESS
UNIT OPERATIONS

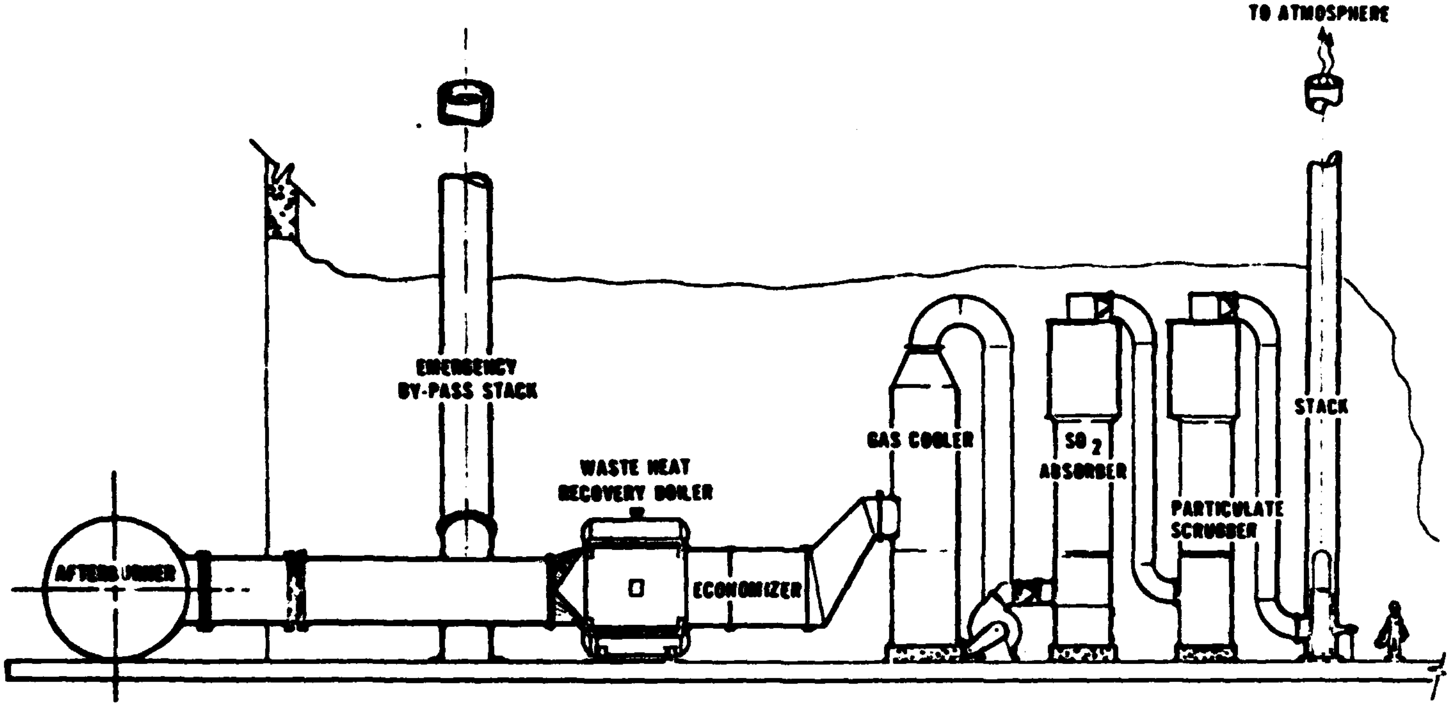


MULTIPLE-HEARTH FURNACE



SLIDING GATE VALVES
EACH SET OF CLOSURES WORK ALTERNATELY

ASH SEAL (3)

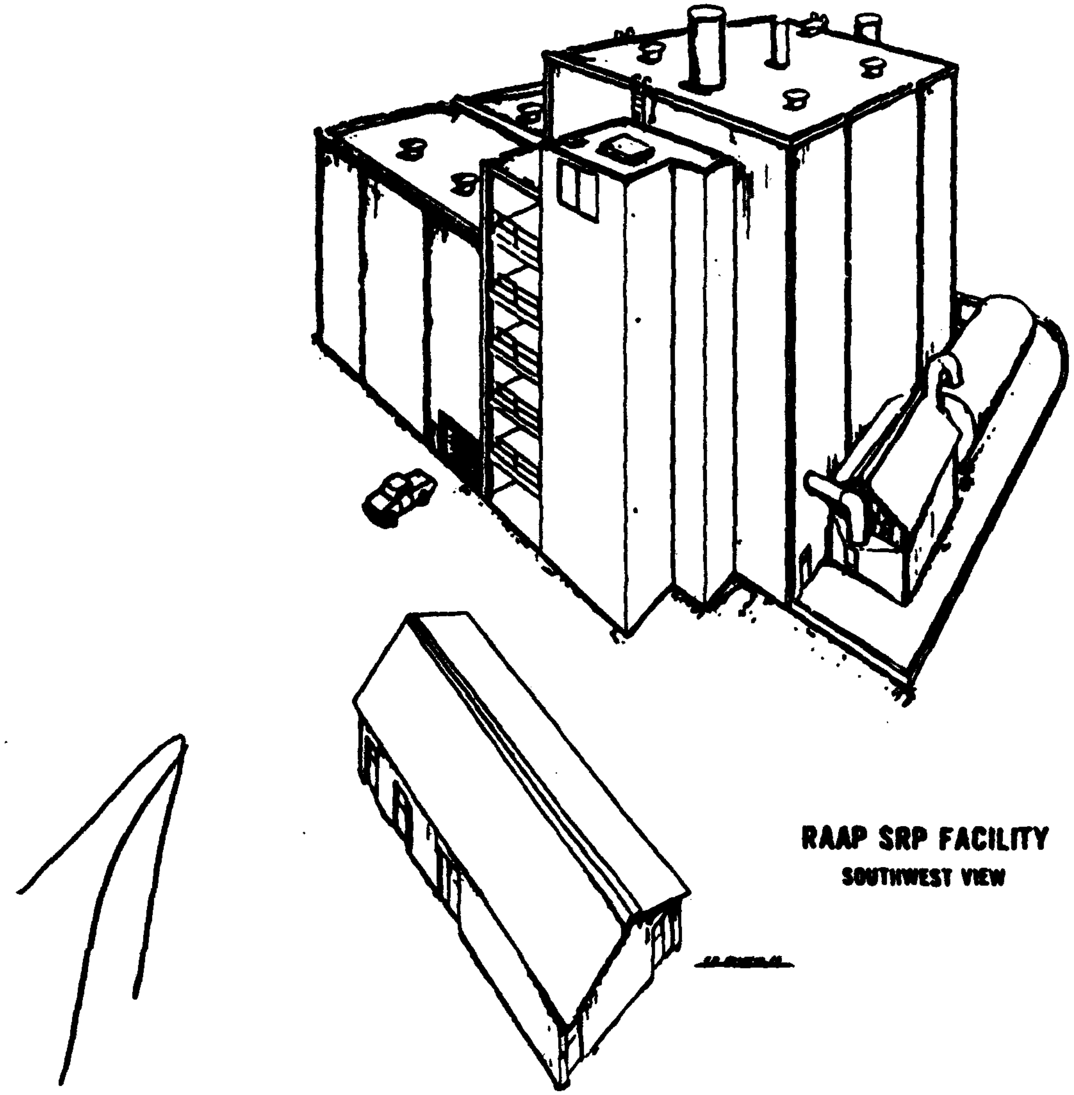


RAAP SRP FACILITY
EAST VIEW OF GAS TRAIN

9 JUNE 1983

PROJECT SCHEDULE

30% DESIGN CONCEPT REVIEW	FEB 1982
VE WORKSHOP	APR
VE APPROVAL MEETING	JUN
60% DESIGN REVIEW	SEP
VE RE-DESIGN REVIEW (40%)	APR 1983
90% DESIGN SUBMITTAL	NOV
FINAL DESIGN PACKAGE TO COE	MAY 1984
DETAILED FACILITY MODEL	JUL (TARGET DATE)
BID ADVERTISEMENT	SEP
CONTRACT AWARD	DEC
START CONSTRUCTION	JAN 1985 (EST'D)
COMPLETE CONSTRUCTION	JUN 1987 (EST'D)
START PROCESS PROVE-OUT	JUL (EST'D)



RAAP SRP FACILITY

SOUTHWEST VIEW

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LOCATION OF VOLATILE BURIED WASTES BY FIELD PORTABLE INSTRUMENTATION

Dr. Gary L. McKown
Battelle, Project Management Division
Office of Hazardous Waste Management
HAPO Building, Fourth Floor
601 Williams Boulevard
Richland, Washington 99352

(509) 943-6922

INTRODUCTION

Contamination of environmental media by volatile organic chemicals has been observed at a wide variety of industrial and government facilities. In particular, volatile halogenated hydrocarbons (VHH) have been shown to pose problems of such magnitude that special regulatory standards are being considered for these materials. (EPA, 1982).

Difficulties are encountered when characterizing a site that involves VHH contamination. Some of the factors which increase the difficulties are:

- There are no standard methods for sampling and analysis for volatile constituents in soil matrices.
- There is good evidence that several of the species may be transformed biologically. (Wood, 1981).
- There is evidence to suggest that the volatile halogenated species may undergo nonlinear absorption in soil matrices. ~~(Richter, 1981).~~

These factors limit the ability to determine source location and strength in the case of buried, non-containerized wastes. Adequate sampling of the subsurface waste deposits is both time-consuming and of questionable validity, and the degradation/retardation complications reduce the appropriateness of "plume-tracking" as a means for determining source characteristics. This paper describes an approach to the sampling and analysis problem which was employed in a recent site characterization effort.

BACKGROUND

An extensive site characterization and groundwater quality assessment, conducted at a government facility in 1981-82, revealed the presence of significant groundwater contamination by VHH. Observed groundwater contamination was emanating from at least five distinct sources. Historical records and past or current operating practices were used to determine source characteristics for all but one of the probable sources. For the source area in question, existing records, maps, and aerial photographs indicated that an area of approximately six acres was used primarily as a burning ground for trash and wooden debris. Aerial photographs showed the existence of various pits, ground stains, and lagoons during the period 1957-1969. Any of the photo-interpreted artifacts could be the source of observed contamination, but most are probably innocuous. The problem is complicated by the presence of a large warehouse building of recent vintage, which covers approximately one-half of the study area.

To evaluate the need for and feasibility of remedial actions in the vicinity of the source area, it was necessary to estimate the location, size, and source strength. Because it was considered likely that shallow groundwater discharged into a surface stream immediately downgradient of the source (resulting in release of the contaminants to the atmosphere), a qualitative study with limited scope was deemed appropriate. The objective of the task, then, was to determine the approximate location, size, and strength of any sources in the study area.

APPROACH

The procedure used in this investigation consisted of the following steps:

- Prepare a coarse grid of boreholes across the area.
- Allow equilibrium to be established within each borehole.
- Obtain air samples from within the borehole.
- Immediately analyze air samples for total hydrocarbon and total halogenated hydrocarbon content.
- Based on the results using the coarse grid, install additional sampling points in selected areas; sample and analyze the interstitial air as before.

Using this procedure, the area can be successively demarcated into zones based on organic vapor content of the boreholes. Elements of the procedure are detailed in the following paragraphs.

BOREHOLE GRID

A grid was established across the area of potential past waste disposal such that utility lines, a concrete pad, and a recent warehouse building were avoided. Nineteen boreholes at nominal 50-ft grid intervals were drilled to a depth of 10 ft below the surface, using a 4-in. solid stem auger. Cutting returns from these boreholes were observed for evidence indicating previous activity. The boreholes were capped with a flat lid and left undisturbed until measurements could be made. After analysis of samples as described below, seven additional boreholes were drilled at 25-ft grid intervals within zones showing high halogen content. Following completion of the analyses, all boreholes were filled to the surface with a 20:1 cement/bentonite grout.

SAMPLING

Samples were collected from the boreholes after a period of about 2 hrs following drilling to allow equilibration. A sample of the air within each borehole was collected by inserting a teflon tube to a depth of approximately 5 ft and using a small battery-powered bellows pump to collect the sample in a 3 liter mylar air bag. The sample was immediately analyzed at the nearby instrument station. After analysis, each sample bag was repeatedly flushed with clean compressed air and evacuated until analysis indicated minimum residual contamination.

ANALYTICAL INSTRUMENTATION

Analysis of the air samples for total volatile hydrocarbon and total halogenated hydrocarbon content was performed using a detector developed by Battelle-Institut e.v. in Frankfurt, Germany. The instrument contains a flame ionization detector (FID) for analysis of hydrocarbons and a potassium-impregnated platinum detector for analysis of halogen content. The gaseous sample (or purge from a water sample) is conducted through a heated entrance port to the detectors, without benefit of chromatographic columns. Therefore, the response time is short, there are no precise chromatographic conditions to maintain, and problems with column degradation or peak tailing are eliminated. An entire analysis requires only about 5 min. Use of a sample pump obviates the need for a carrier gas. Location of the sample pump behind the detectors eliminates potential interactions between the sample and the pump mechanism.

The air sample is completely burned within the FID stage, and halogen content of the combustion products is measured by the platinum detector. Readout of signals from both detectors was recorded on a dual-channel strip chart recorder, thus allowing direct comparison of the results. Since the sample is introduced continuously, signals remain at a constant level after the detectors equilibrate. The height of the signals correspond to sample constituency. The instrument is calibrated by introducing air samples containing known concentrations of hydrocarbons and halogenated hydrocarbons and measuring the height of the resulting signals. For the present work, samples containing 50, 100, and 200 ppb of trichloroethylene were used as calibration standards. Thus, the halogen content is obtained relative to trichloroethylene, and results are interpreted comparatively.

RESULTS

Analysis of air samples from the boreholes provided the results given in Table 1. While the instrument readout yields a direct measurement of concentration, the minimal calibration procedure that was used forces a semiquantitative interpretation of the data.

TABLE 1. Borehole Analysis Results (L = Low, H = High, M = Moderate, VL = Very Low or zero, VH = Very High)

Boreholes Coordinates	Hydrocarbon	Halogen	Boreholes Coordinates	Hydrocarbon	Halogen
E0N0	L	M	E50N200	M	VL
E0N50	L	L	E95N-50	L	VL
E0N100	L	L	E110N0	M	VL
E0N150	VL	VL	E100N50	H	VL
E0N200	VL	VL	E100N100	VL	VL
E0N-25	H	H	E100N150	M	VL
E0N-50	L	M	E100N200	M	VL
E25N0	VL	H	E150N-50	M	M
E25N-25	VL	VH	E150N0	L	VH
E50N-50	L	VL	E150N-50	M	VH
E50N0	M	VL	E125N-50	M	M
E50N50	M	VL	E125N-25	M	VH

High concentrations both of hydrocarbons and chlorinated hydrocarbons were found at several locations within the study area. The high hydrocarbon levels were obtained from boreholes drilled below the water table and which also returned ashes and other debris indicative of trash disposal during the drilling. These readings are thought to be due to anaerobic decomposition products, principally methane. At least two of the locations showing high hydrocarbon content correspond to what appears to be piles of trash in older aerial photographs.

The boreholes showing high halogen content were concentrated in two zones, see Figure 1. The zones correspond to a debris pile (Zone A in the figure) and lower cell of a two-part lagoon shown in aerial photographs in the 1957-1969 time period. Other pits and artifacts shown in the photographs do not appear, from the borehole results, to have been scenes of VHH disposal.

Both zones showing VHH contamination are within areas where the drilling returns indicate highly permeable sands and gravel, and the water table is at the same level as the nearby stream elevation. The original hypothesis that contaminated groundwater discharges to the surface system thus appears to be correct.

CONCLUSIONS

The following conclusions were made regarding this work:

- The location, approximate size, and relative strength of waste sources within the study area were established. Evidence was obtained for hydrologic interconnection of contaminated groundwater with surface streams, thus indicating the minimal need for source control remedial actions.

- Comparative results using simple analytical procedures and borehole air sampling was shown to be a fast, effective method for locating buried sources of volatile halogenated hydrocarbons. The entire sequence of events as described above, including borehole grouting, occurred over a three-day period.

REFERENCES

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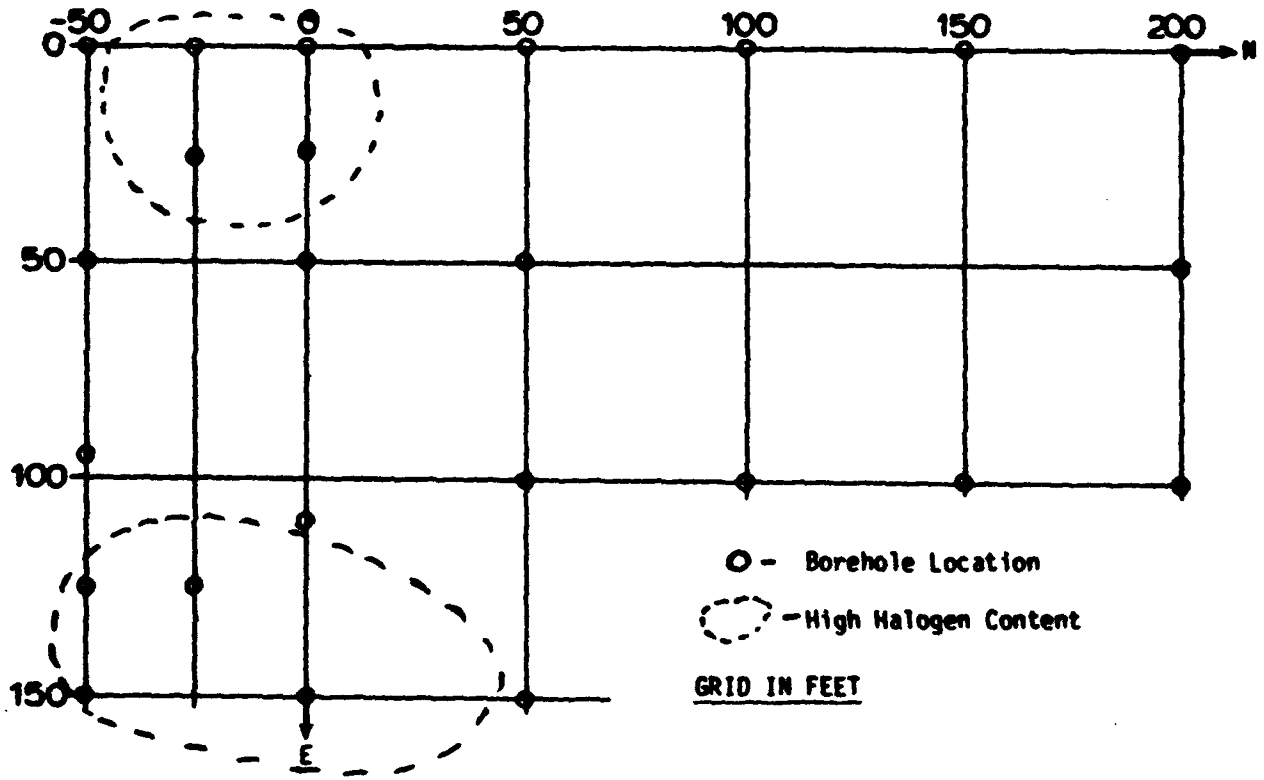

FIGURE 1. Grid Layout and Areas Showing High Volatile Halogenated Hydrocarbon Readings

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PRACTICAL APPLICATION OF EARTH RESISTIVITY METHODS IN PHASE II OF THE INSTALLATION RESTORATION PROGRAM

By

H. Dan Harman, Jr., P.G.

and

James N. Baker

Engineering-Science, Inc.
57 Executive Park South
Atlanta, Georgia 30329
(404) 325-0770

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INTRODUCTION

The Department of Defense (DOD) Installation Restoration Program (IRP) establishes DOD policy to identify and evaluate suspected problems associated with past hazardous waste contamination. Phase I of the IRP is the initial assessment and records search of sites that potentially contain hazardous waste. Phase II is the confirmation and quantification of potentially hazardous waste sites. Phase III, the technology base development, and Phase IV, the remedial actions, will follow the identification of hazardous waste sites.

Within Phase II of the IRP, the most important objectives are to determine if suspected contamination of a site exists, and if it does, then adequately describe the site geologic conditions and define the extent of subsurface as well as surface contamination. These two objectives are accomplished through field investigations of sites. These field investigations should be cost-effective and provide critical data to advance further investigation activities in a technically sound manner.

One geophysical method of field investigation is the electrical resistivity (ER) survey. The ER survey, if effective and properly applied, can yield data interpretations related to both the site geologic conditions and to the definitions of ground-water contamination areas.

This paper discusses the potential utilization of electrical resistivity surveys during Phase II of the IRP. The successful utilization of ER is based on a combination of both technical approach and knowledge and skill of the user. As examples of ER utilization, two case studies involving ER surveys are described. The technical approaches and lessons learned during these two example studies may be applicable to the Phase II site investigations of the IRP.

ELECTRICAL RESISTIVITY

Electrical resistivity is one type of surface geophysical method which uses the principles of electricity. Electric current from a series of batteries is conducted through two electrodes which are pushed into the ground. The resulting voltage drop produced by the current is measured across the other two electrodes which are also pushed into the ground. The instrument measurement is normally expressed in ohm-feet and is called apparent resistivity. The apparent resistivity is affected by geologic and ground-water conditions as well as by man-made conditions.

The criteria for ER utilization can be summarized in four main items. These items, shown in Figure 1, are Best Usage Areas, Limiting Factors, Advantages and Disadvantages. ER can best be utilized in open fields that have no surface or subsurface contraints. Also, ER is easiest to interpret when the geology is homogeneous. The limiting factors for ER utilization are surface constraints such as asphalt or concrete and ponded water. Subsurface constraints are pipelines, buried containers and solidified wastes. Highly variable geology and mineralized ground water such as salt water intrusion near oceans can impede the proper interpretation of ER data.

Electrical resistivity affords the user some essential advantages. These advantages are the capability to identify vertical as well as horizontal anomalies in the subsurface. Investigation depths can be as deep as 1,000 feet, but the least expensive equipment known by the authors will investigate 300 feet below the ground. Also, vertical electrical soundings using the "Modified Wenner" method (to be explained in the case studies) can be relatively accurate in actual geologic correlations at depth.

The disadvantages inherent in ER are that the probes must be pushed into the ground, ER can be relatively time consuming and ER requires a 2- to 3-man crew for the most effective utilization. These few disadvantages are overcome by the versatility and effectiveness of the ER to give the needed subsurface data.

The utilization of ER consists of two main techniques. These are horizontal profiles and vertical soundings. Horizontal profiles are apparent resistivity measurements at a single zone below the surface taken at numerous locations over an area. Vertical soundings are apparent resistivity measurements at various depths below the surface at one location. Figure 2 illustrates one method of the horizontal profile technique. The Wenner array of equal electrode spacing enables ER measurements to be made at one general depth zone at numerous locations on a site. A recommended selection of electode "A" spacing for a profile should be between one and two times the depth of interest (Bison, 1975). As illustrated in Figure 2, the electrode spacings are at equal distances. The current is conducted through the C and C' electrodes and the voltage drop is measured between the P and P' electrodes. The formula for calculating the apparent resistivity using the Wenner method is as follows:

$$p = A\ (2\Pi \frac{V}{I})$$

Where: p = apparent resistivity in ohm-feet
A = electrode "A" spacing between individual electrodes in feet
Π = 3.14
v = voltage in millivolts
I = current in milliamperes

The Bison Model 2350B, used by the authors, internally calculates the factor ($2\Pi\frac{V}{I}$) so one must only multiply the "A" spacing times the Bison dial reading and scale multiplier to obtain the apparent resistivity.

FIGURE 1

GUIDELINES FOR EARTH RESISTIVITY USE

BEST USAGE AREAS

OPEN FIELD; NO SURFACE OR SUBSURFACE CONSTRAINTS; HOMOGENEOUS GEOLOGY

LIMITING FACTORS

ASPHALT AND/OR CONCRETE AREAS; PONDED WATER; PIPELINES, ELECTRICAL LINES AND OTHER CONDUCTORS; BURIED CONTAINERS; SOLIDIFIED WASTES; HIGHLY VARIABLE GEOLOGY; MINERALIZED GROUND WATER

ADVANTAGES

VERTICAL AND HORIZONTAL ANOMALIES IDENTIFIABLE; SOUNDING DEPTH CAN BE RELATIVELY ACCURATE; DEPTH RANGE OF 300 FEET WITH LEAST EXPENSIVE EQUIPMENT

DISADVANTAGES

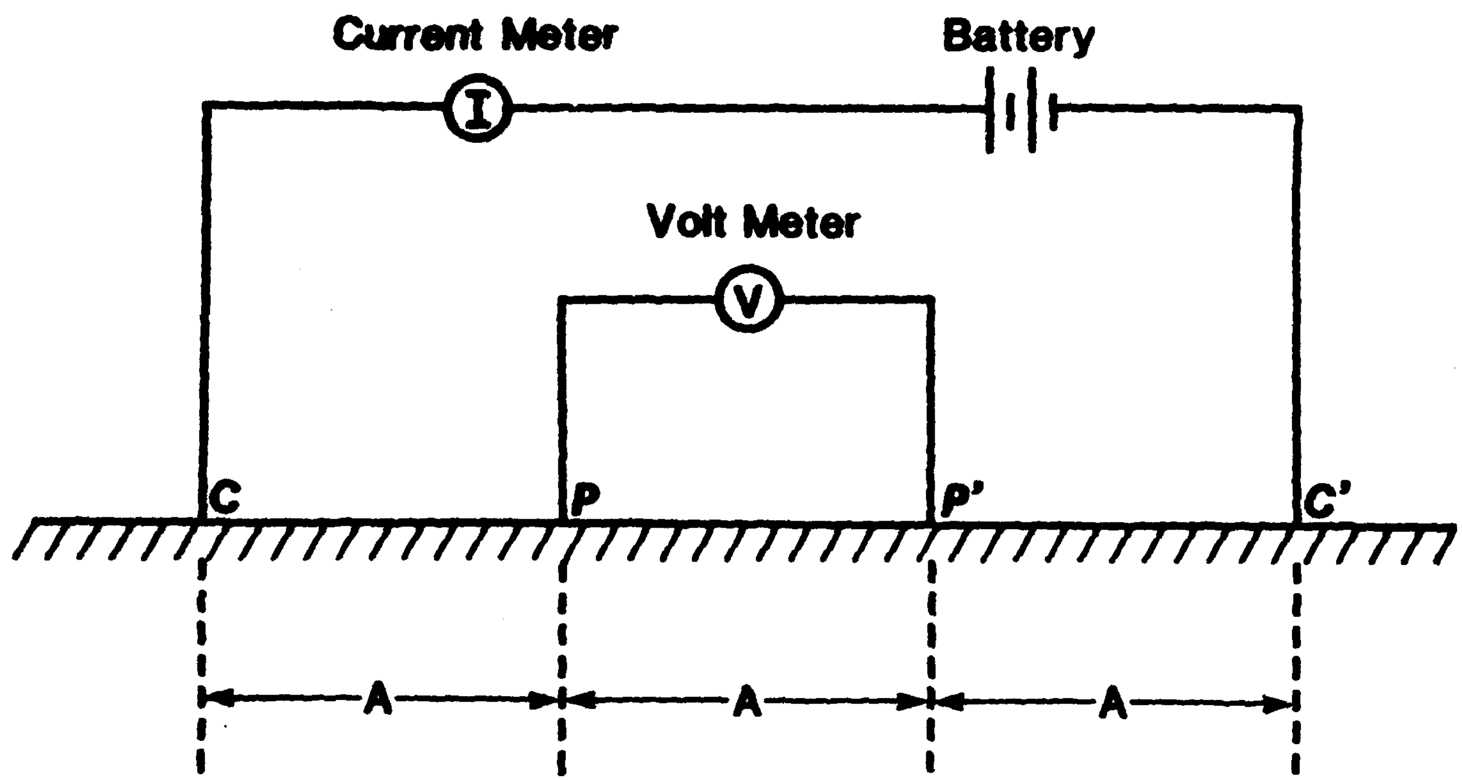
2- to 3- MAN OPERATION; RELATIVELY TIME CONSUMING; PROBES MUST BE PLACED INTO SOIL

FIGURE 2

WENNER ARRAY
DIAGRAM OF ELECTRODE SPACING

Formula for Apparent Resistivity

$$\rho = A(2\pi \frac{V}{I})$$



SOURCE: Bison, 1975

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Figure 3 illustrates one method of the second ER technique, vertical soundings. Vertical soundings are measurements of apparent resistivity at various depths at one location. The depths at which apparent resistivity measurements are made can be varied depending on the "Modified Wenner" electrode spacing selected (Carrington and Watson, 1981). The authors normally obtain measurements at two-foot intervals to a depth of 100 feet. The authors have found that by using the "Modified Wenner" method, electrode spacing across the land surface approximately equals the depth of investigation within the subsurface. As in the Wenner method, the current in the "Modified Wenner" method is conducted through the outer electrodes and the voltage drop is measured between the inner electrodes. In the "Modified Wenner" method, the outer electrodes remain stationary while the inner electrodes are moved at regular intervals outward from the preselected geoelectric center of the array. The formula for apparent resistivity at an individual electrode spacing is as follows:

$$p = (2\Pi R)\left[\frac{1}{1/r_1-1/r_2-1/r_3+1/r_4}\right]$$

where p = apparent resistivity in ohm-feet
Π = 3.14
R = resistivity in ohms
($R = \frac{V}{I}$)
r_1, r_2, r_3, r_4 = distances between individual electrodes in feet

The factor ($2\Pi R$) is again internally calculated by the Bison 2350 B unit. The factor in brackets is a constant value in feet for a particular electrode array. Examples of the constant values are shown in tables in the discussions of case studies.

GLACIAL TILL CASE STUDY

An ER survey was conducted at a site located in glacial till. Glacial till is unsorted and nonstratified material deposited by glaciers. It is composed of various sizes of rock fragments from clay size to boulder size. The history of the site included the disposal of hazardous organic as well as metal contaminants. Organics such as benzene, ethylbenzene, chlorobenzene, methylene chloride, toluene, trichloroethylene and phenolics were analyzed from ground-water monitoring wells installed after the ER survey. Metals such as chromium, copper, mercury, nickel and zinc were also analyzed from the ground-water samples.

Figure 4 illustrates a vertical sounding obtained at the site. A test boring located near the sounding is also shown to illustrate the close correlation between the sounding and the boring log. The water table and top of rock were effectively correlated. The apparent resistivity graph shows the numerous variations in the subsurface apparent resistivity. The very high value between the ground surface and five feet below ground is interpreted as dry sediments. The water table, encountered at 7.5 feet in the boring, is interpreted to be at 8 feet on

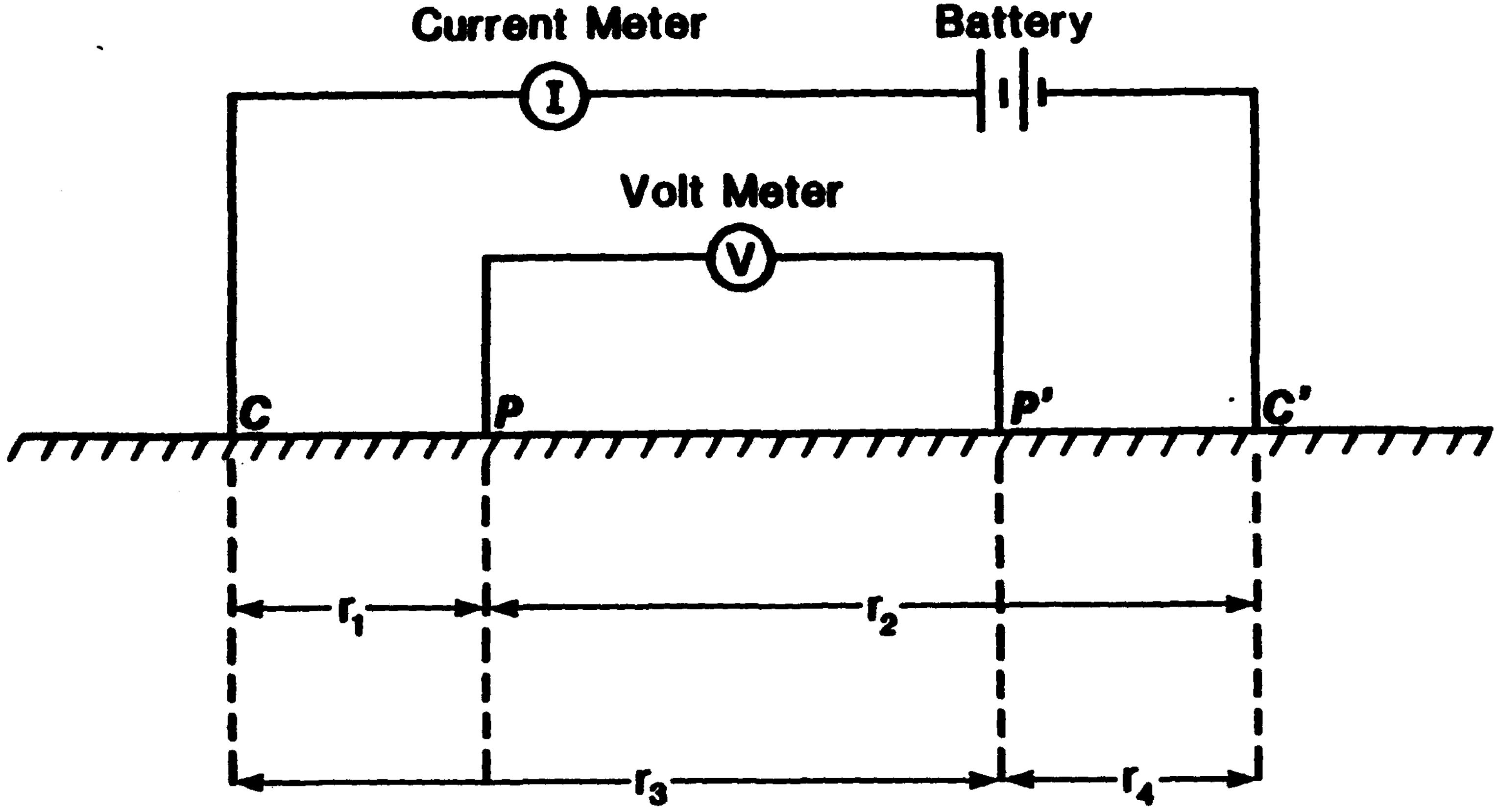
FIGURE 3

"MODIFIED WENNER" ARRAY

DIAGRAM OF ELECTRODE SPACING

Formula for Apparent Resistivity

$$\rho = (2\pi R)\left[\frac{1}{1/r_1 - 1/r_2 - 1/r_3 + 1/r_4}\right]$$



SOURCE: Carrington & Watson, 1981

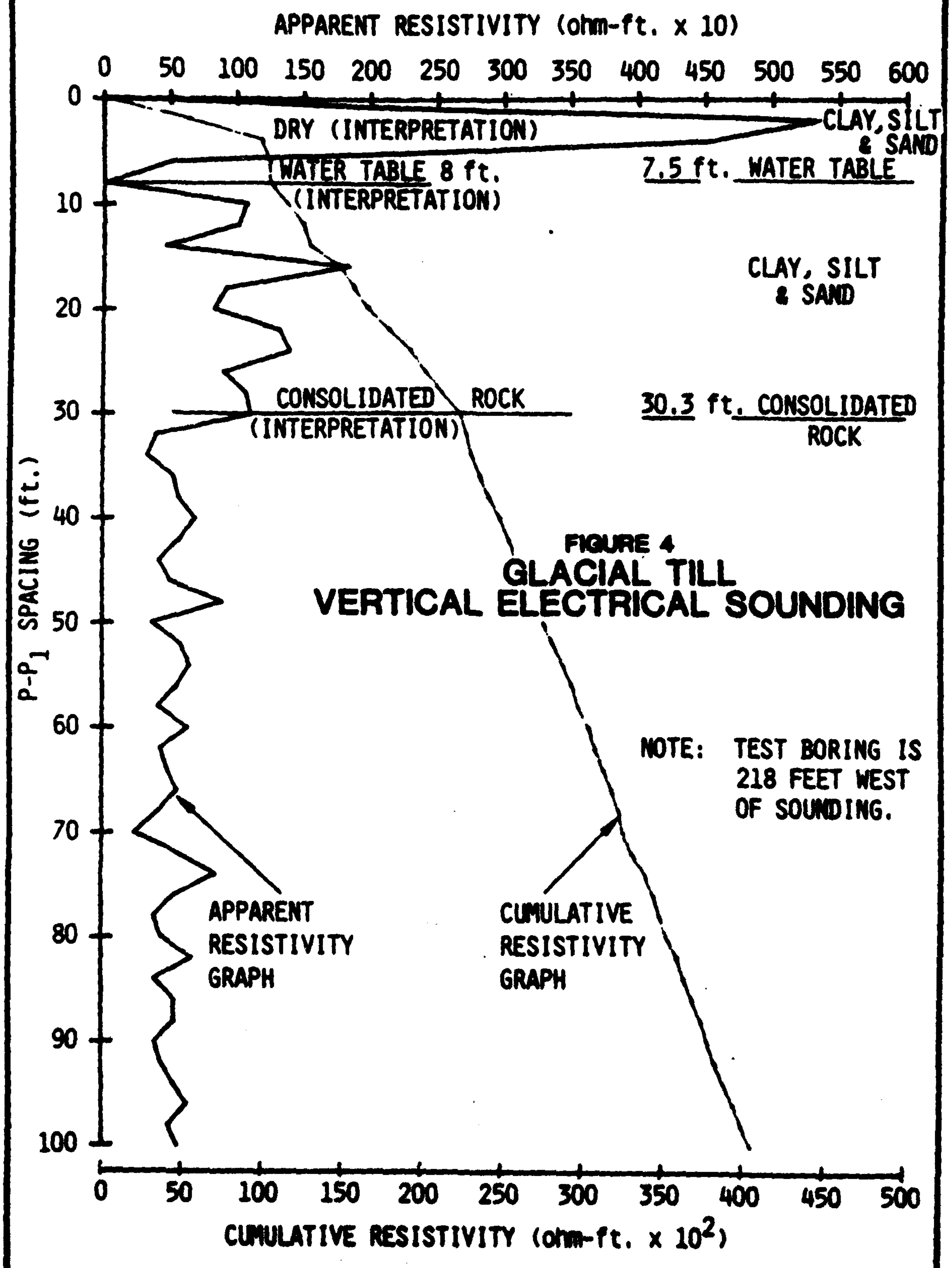


FIGURE 4
GLACIAL TILL
VERTICAL ELECTRICAL SOUNDING

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the sounding. Note the very low apparent resistivity value at 8 feet. A major shift in the apparent resistivity graph and the cumulative resistivity graph occurs at 30 feet. This shift is interpreted as the topof rock. The rock type is shale so a decrease in the resistivity would be expected. Below 30 feet variations in the apparent resistivity graph are interpreted as minor fractures and/or lithologic changes. The boring was terminated at 30.3 feet so the deeper interpretations have not been confirmed. Table 1 lists the actual meter readings and electrode spacings and the resulting calculations made to determine the apparent resistivity and cumulative resistivity for the vertical electrical sounding (VES) shown in Figure 3. Table 1 was prepared using a special computer program.

Following the soundings, geoelectric zones were selected in which horizontal electrical profiles were conducted. Geoelectric zones of approximately 5, 10, 25 and 50 feet below ground were selected. Figure 5 is a result of the profiles on and surrounding the site. Physical constraints such as pipelines and concrete pods prevented profiles over a majority of the site itself. In Figure 5, the significant resistivity anomalies (values less than 40 ohm-feet) are shown in separate areas for each electrode "A" spacing of 5, 10, 25 and 50 feet. Background profile values ranged from 150 to 650 ohm-feet. Note that off-site toward the southwest two areas were identified as resistivity anomalies at approximately 25 and 50 feet deep. These areas are not downgradient of the site. The downgradient direction is north and northeast. The areas were later determined to be areas of a previous landfill not associated with the site under investigation. The anomalies north of the site in the widest area of the river alluvium were not associated with hazardous wastes but were found to be asociated with lithologic changes in the subsurface. All other anomalies north and northeast of the site were associated with hazardous wastes in the subsurface. Leachate was also visible in these areas.

CRYSTALLINE ROCK OVERBURDEN CASE STUDY

An ER survey was conducted at a site located in crystalline rock overburden. The crystalline rock oveburden was composed of clay, silt, sand and weathered rock. The crystalline rock was hornblende-biotite schist. Schist is a metamorphic rock. The history of this site included a surface impoundment used to dispose of acidic wastes with high concentrations of lead. The surface impoundment was subsequently closed, but stream water quality downgradient of the site was impacted by contaminated ground water entering the stream.

Figure 6 illustrates a vertical sounding obtained at the site. A test boring located near the sounding is also shown to illustrate the close correlation between the sounding and the boring log. Significant apparent resistivity graph changes correlate well with lithologic changes in the boring log. Note the relatively stabilized apparent resistivity graph between 18 and 42 feet and between 58 and 80 feet. These two zones on the sounding graph correlate with the sandy silt (18 to 42 feet) and weathered rock (58 to 84 feet) on the boring log. Also, the relatively high apparent resistivity between 54 and 58 feet on the sounding graph correlates with the sand zone between 52 and 58 feet on

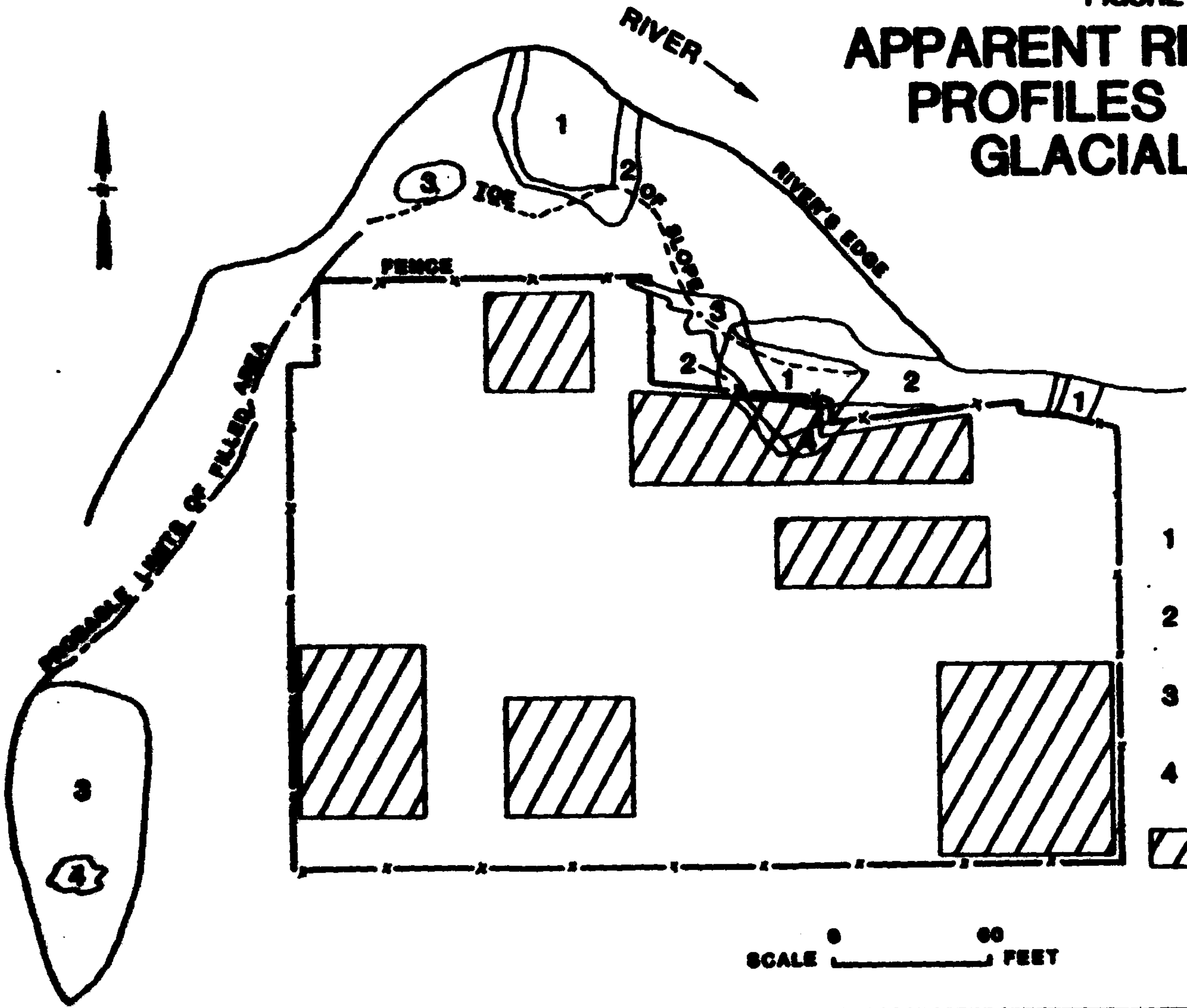
TABLE 1

GLACIAL TILL VES DATA

p-pl spacing (feet)	dial reading (ohms)	scale multiplier	corrected reading (ohms)	*k (feet)	apparent resistivity (ohm-ft)	cumulative resistivity (ohm-ft)
2.00	21.40	0.10	2.14	2499.80	5349.57	5349.57
4.00	36.20	0.10	3.62	1249.50	4523.19	9872.76
6.00	62.00	0.01	0.62	832.60	516.21	10388.97
8.00	2.00	0.01	0.02	624.00	12.48	10401.45
10.00	214.60	0.01	2.15	498.80	1070.42	11471.88
12.00	242.80	0.01	2.43	415.20	1008.11	12479.98
14.00	13.00	0.10	1.30	355.40	462.02	12942.00
16.00	59.00	0.10	5.90	310.50	1831.95	14773.95
18.00	33.40	0.10	3.34	275.50	920.17	15694.12
20.00	33.40	0.10	3.34	247.50	826.65	16520.77
22.00	58.80	0.10	5.88	224.50	1320.06	17840.83
24.00	68.00	0.10	6.80	205.30	1396.04	19236.87
26.00	47.60	0.10	4.76	189.10	900.12	20136.99
28.00	61.00	0.10	6.10	175.10	1068.11	21205.10
30.00	67.60	0.10	6.76	162.90	1101.20	22306.30
32.00	26.00	0.10	2.60	152.30	395.98	22702.28
34.00	23.20	0.10	2.32	142.80	331.30	23033.58
36.00	39.00	0.10	3.90	134.40	524.16	23557.74
38.00	44.80	0.10	4.48	126.80	568.06	24125.80
40.00	57.20	0.10	5.72	120.00	686.40	24812.20
42.00	50.00	0.10	5.00	113.80	569.00	25381.20
44.00	38.80	0.10	3.88	108.10	419.43	25800.63
46.00	49.00	0.10	4.90	102.90	504.21	26304.84
48.00	90.60	0.10	9.06	98.20	889.69	27194.53
50.00	39.40	0.10	3.94	93.80	369.57	27564.11
52.00	65.00	0.10	6.50	89.70	583.05	28147.16
54.00	75.00	0.10	7.50	85.80	650.36	28797.52
56.00	67.40	0.10	6.74	82.30	554.70	29352.22
58.00	52.60	0.10	5.26	79.00	415.54	29767.76
60.00	84.00	0.10	8.40	75.80	636.72	30404.48
62.00	59.80	0.10	5.98	72.90	435.94	30840.42
64.00	69.40	0.10	6.94	70.10	486.49	31326.92
66.00	82.80	0.10	8.28	67.50	558.90	31885.82
68.00	64.40	0.10	6.44	65.00	418.60	32304.42
70.00	38.00	0.10	3.80	62.70	238.26	32542.68
72.00	93.80	0.10	9.38	60.40	566.55	33109.23
74.00	145.60	0.10	14.56	58.30	848.85	33958.08
76.00	95.80	0.10	9.58	56.30	539.35	34497.43
78.00	71.20	0.10	7.12	54.40	387.33	34884.76
80.00	84.80	0.10	8.48	52.50	445.20	35329.96
82.00	132.80	0.10	13.28	50.70	673.30	36003.26
84.00	80.00	0.10	8.00	49.00	392.00	36395.26
86.00	114.00	0.10	11.40	47.40	540.36	36935.62
88.00	118.00	0.10	11.80	45.80	544.10	37479.72
90.00	90.20	0.10	9.02	44.30	399.59	37879.31
92.00	103.40	0.10	10.34	42.80	442.55	38321.86
94.00	129.00	0.10	12.90	41.40	534.06	38855.92
96.00	159.40	0.10	15.94	40.10	639.19	39495.11
98.00	128.00	0.10	12.80	38.80	496.64	39991.75
100.00	151.40	0.10	15.14	37.50	567.75	40559.50

FIGURE 5

APPARENT RESISTIVITY PROFILES WITHIN GLACIAL TILL



LEGEND

1 SIGNIFICANT RESISTIVITY ANOMALY AT ELECTRODE SPACING OF 5 FEET

2 SIGNIFICANT RESISTIVITY ANOMALY AT ELECTRODE SPACING OF 10 FEET

3 SIGNIFICANT RESISTIVITY ANOMALY AT ELECTRODE SPACING OF 25 FEET

4 SIGNIFICANT RESISTIVITY ANOMALY AT ELECTRODE SPACING OF 60 FEET

POTENTIAL SOURCES OF CONTAMINATION

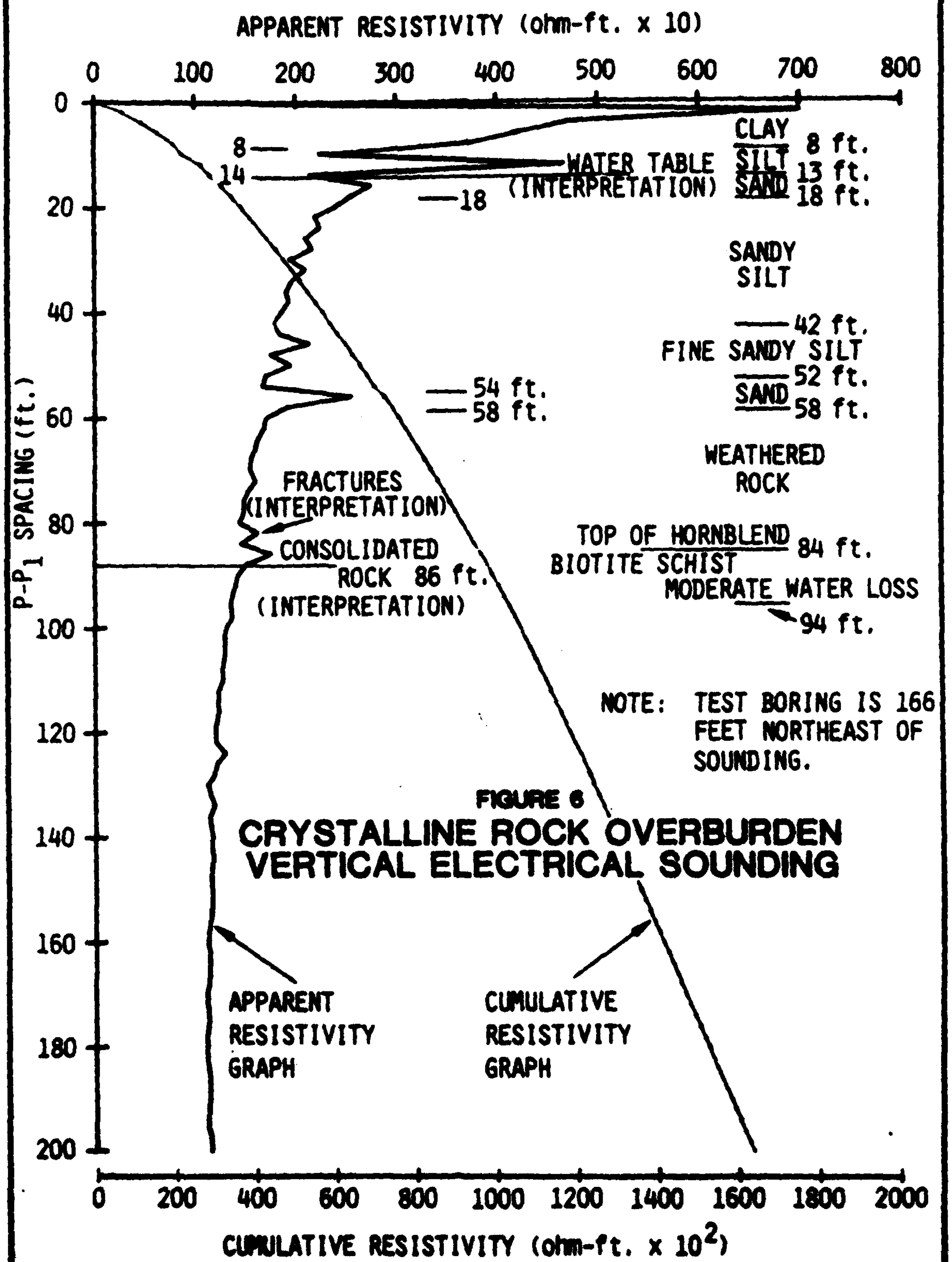


FIGURE 6

CRYSTALLINE ROCK OVERBURDEN VERTICAL ELECTRICAL SOUNDING the boring log. Note that the driller indicated moderate water loss while drilling between 84 and 94 feet. This water loss zone is indicated on the sounding graph as fractures between 80 and 86 feet. Below 86 feet on the sounding graph the resistivity values do not vary substantially. This is interpreted as consolidated rock with little or no fractures. This sounding investigation was carried to a depth of 200 feet, but the boring was terminated at 94 feet. Table 2 lists the meter readings and electrode spacings for the sounding shown in Figure 6.

Following the soundings, geoelectric zones of approximately 10, 30, 60 and 100 feet below the subsurface were selected for profiling. Figures 7, 8, 9 and 10 are a result of the profiles on and surrounding the site. Several physical constraints such as pipelines, fences and access permission limited the number of profile stations in the home subdivision downgradient of the site. Figure 7 is an apparent resistivity profile map showing the profile station locations, resistivity values and contouring of the most significant anomalies. The electrode spacing is 10 feet. This zone is above the water table. The most significant anomalies, those with values less than 500 ohm-feet are located around the closed surface impoundment and just north of the stream confluence.

Figure 8 is an apparent resistivity profile map using an electrode "A" spacing of 30 feet. This zone is below the water table. The most significant anomalies are more aerially extensive and the values are generally lower than those of the previous profile at 10 feet. Note the length of the east stream that is interpreted to be impacted by contaminated ground-water discharge. Also note the contouring of a suspected contamination plume from the west end of the impoundment to the west stream. This plume was confirmed by surface water quality measurements.

Figure 9 is an apparent resistivity profile map using an electrode "A" spacing of 60 feet. This zone is within the weathered rock zone just above the top of rock. It was interpreted as the most seriously contaminated zone. The values are less than 200 ohm-feet in a broad area from the surface impoundment to the east stream. Monitoring wells confirmed the presence of ground-water contamination in this zone.

Figure 10 is an apparent resistivity profile map using an electrode "A" spacing of 100 feet. This zone is within consolidated rock. The resistivity anomaly is limited in aerial extent and the values are greater than 200 ohm-feet. The anomaly may indicate an area of fractures within the rock.

CONCLUSION

Electrical resistivity surveys utilized as exploration techniques can be very cost-effective in gathering geologic and ground-water data during IRP Phase II hazardous waste site investigations. Both soundings and profiles, if properly conducted and interpreted, can guide the placement of ground-water monitoring wells. The wells can be effectively located to intersect suspected ground-water contamination. The geophysical approach prior to drilling is preferred by the authors

TABLE 2

CRYSTALLINE ROCK OVERBURDEN VES DATA

p-pl spacing (feet)	dial reading (ohms)	scale multiplier	corrected reading (ohms)	[illegible] (feet)	apparent resistivity (ohm-ft)	cumulative resistivity (ohm-ft)
2.00	7.00	0.10	0.70	10000.00	7000.00	7000.00
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

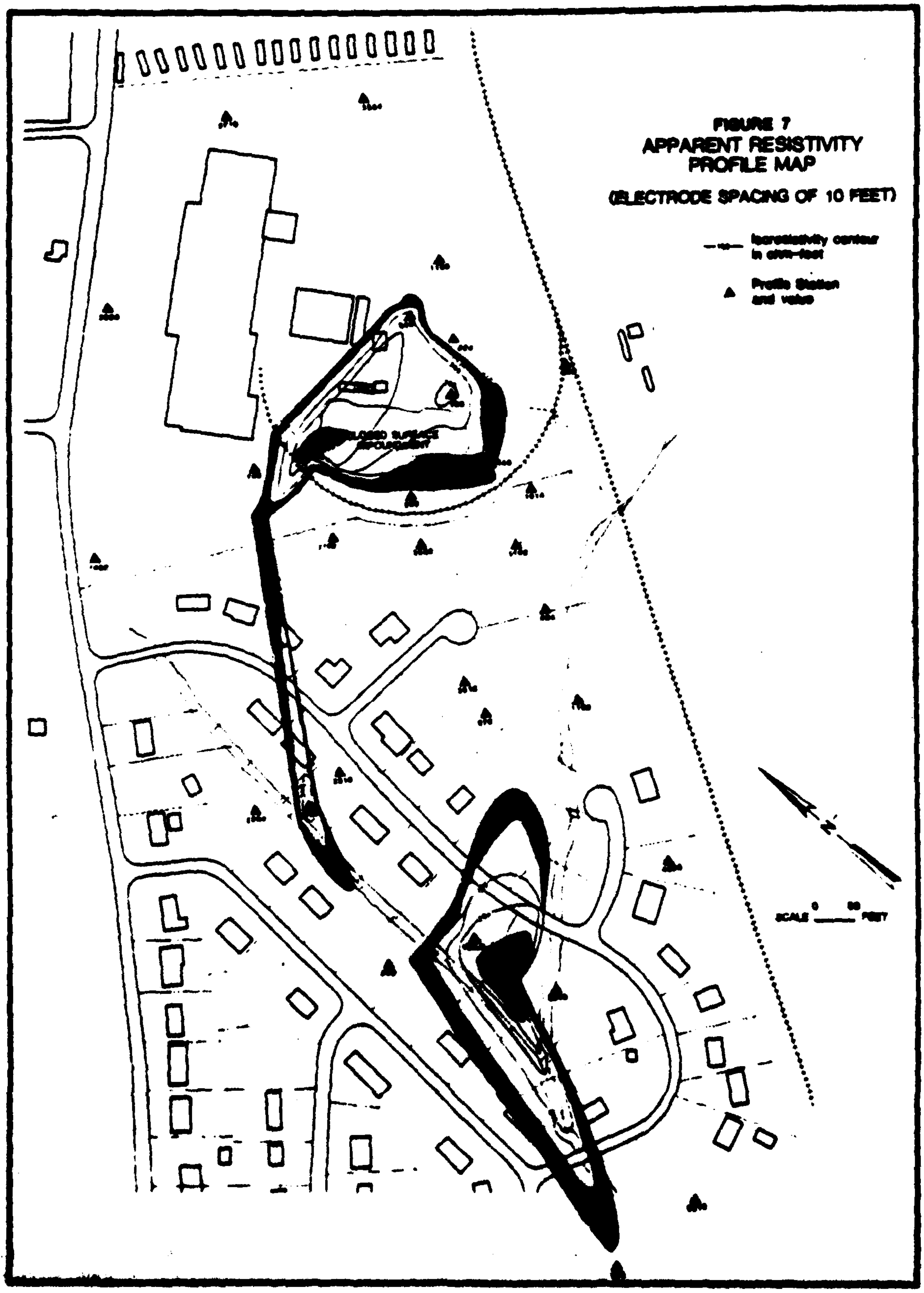


FIGURE 7
APPARENT RESISTIVITY
PROFILE MAP
(ELECTRODE SPACING OF 10 FEET)
Isoresistivity contour in ohm-feet
Profile Station and value
CLOSED SURFACE IMPOUNDMENT
SCALE 0 50 FEET

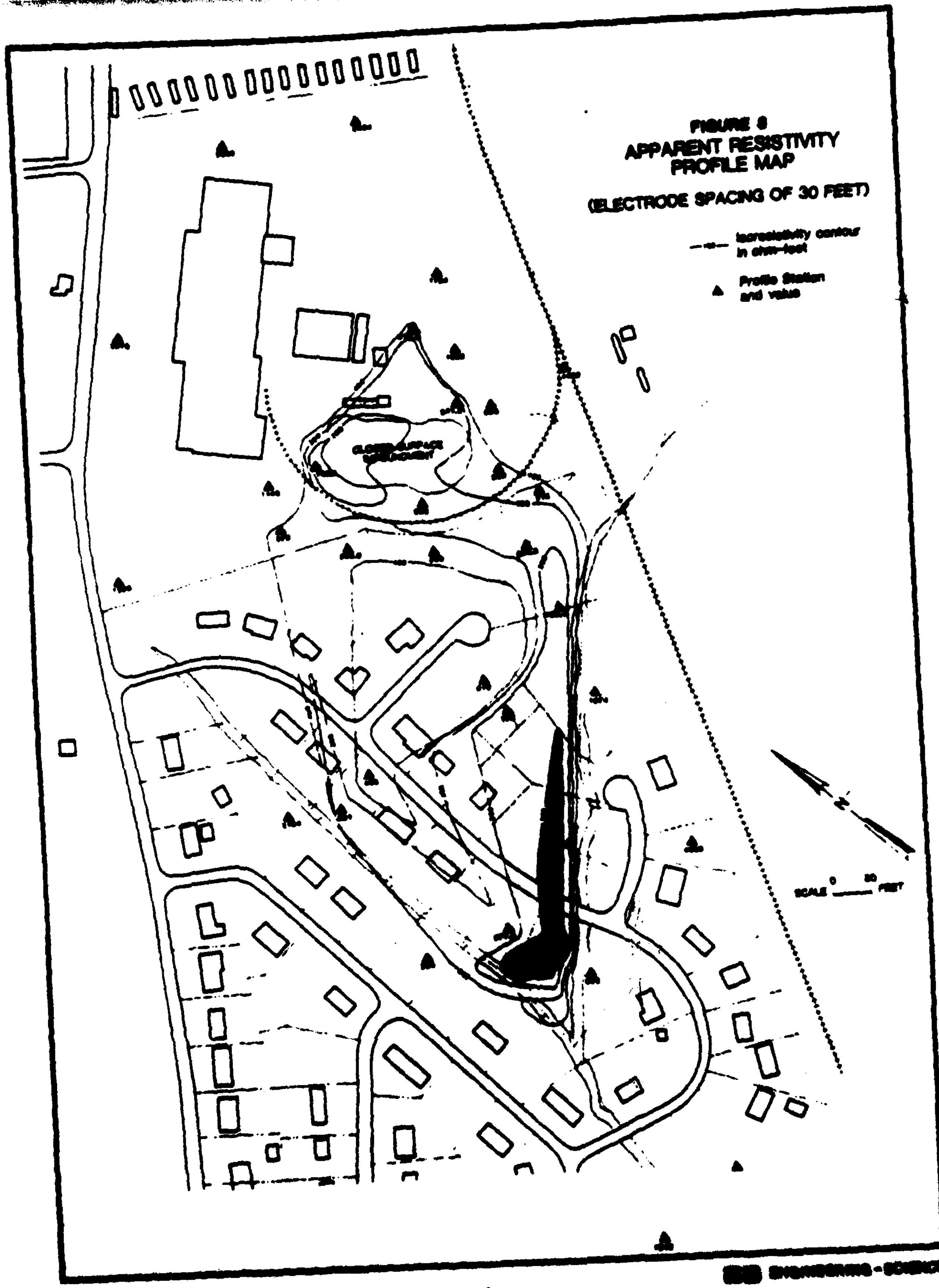


FIGURE 8
APPARENT RESISTIVITY
PROFILE MAP
(ELECTRODE SPACING OF 30 FEET)

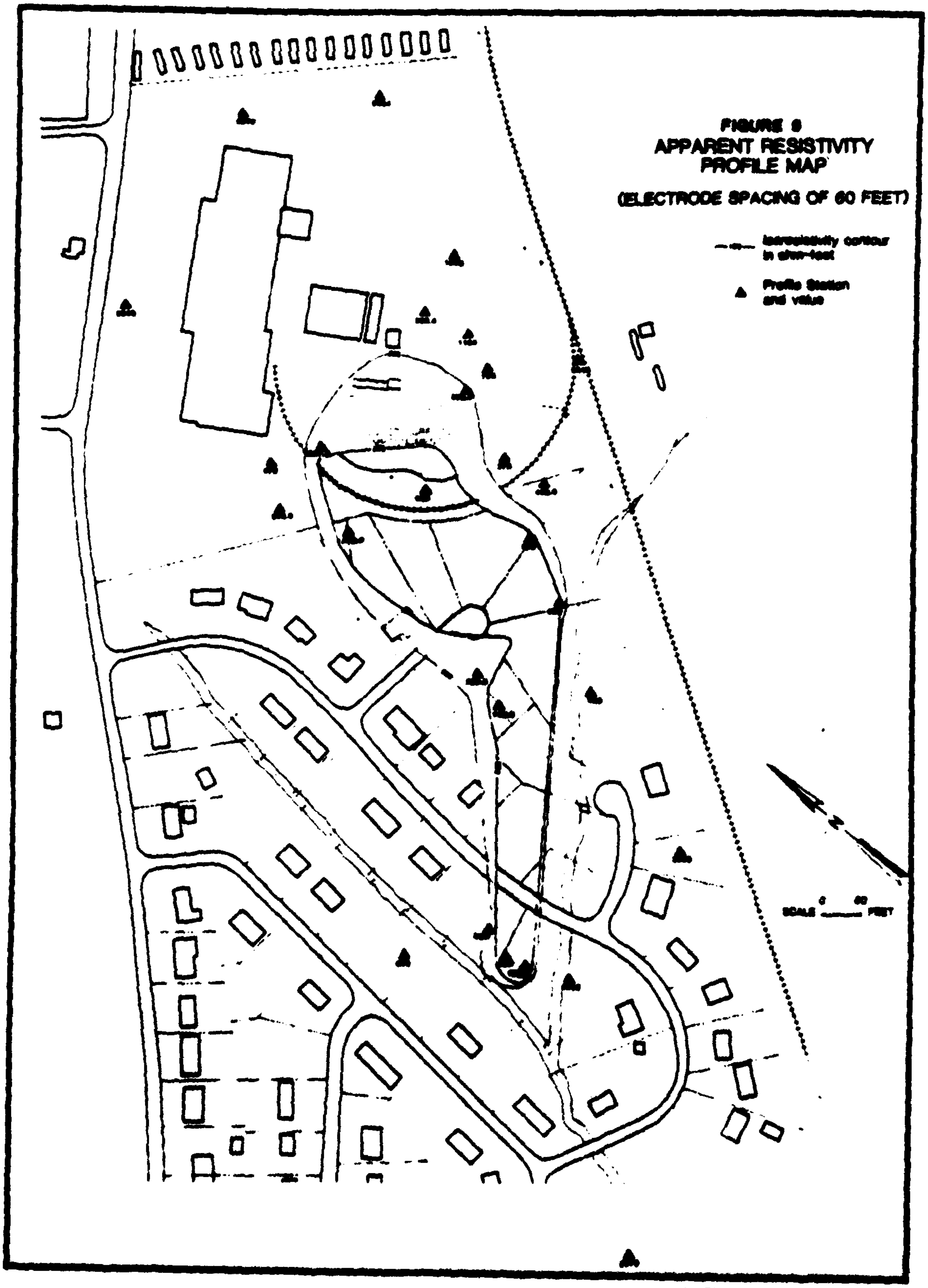


FIGURE 9
APPARENT RESISTIVITY
PROFILE MAP

(ELECTRODE SPACING OF 60 FEET)

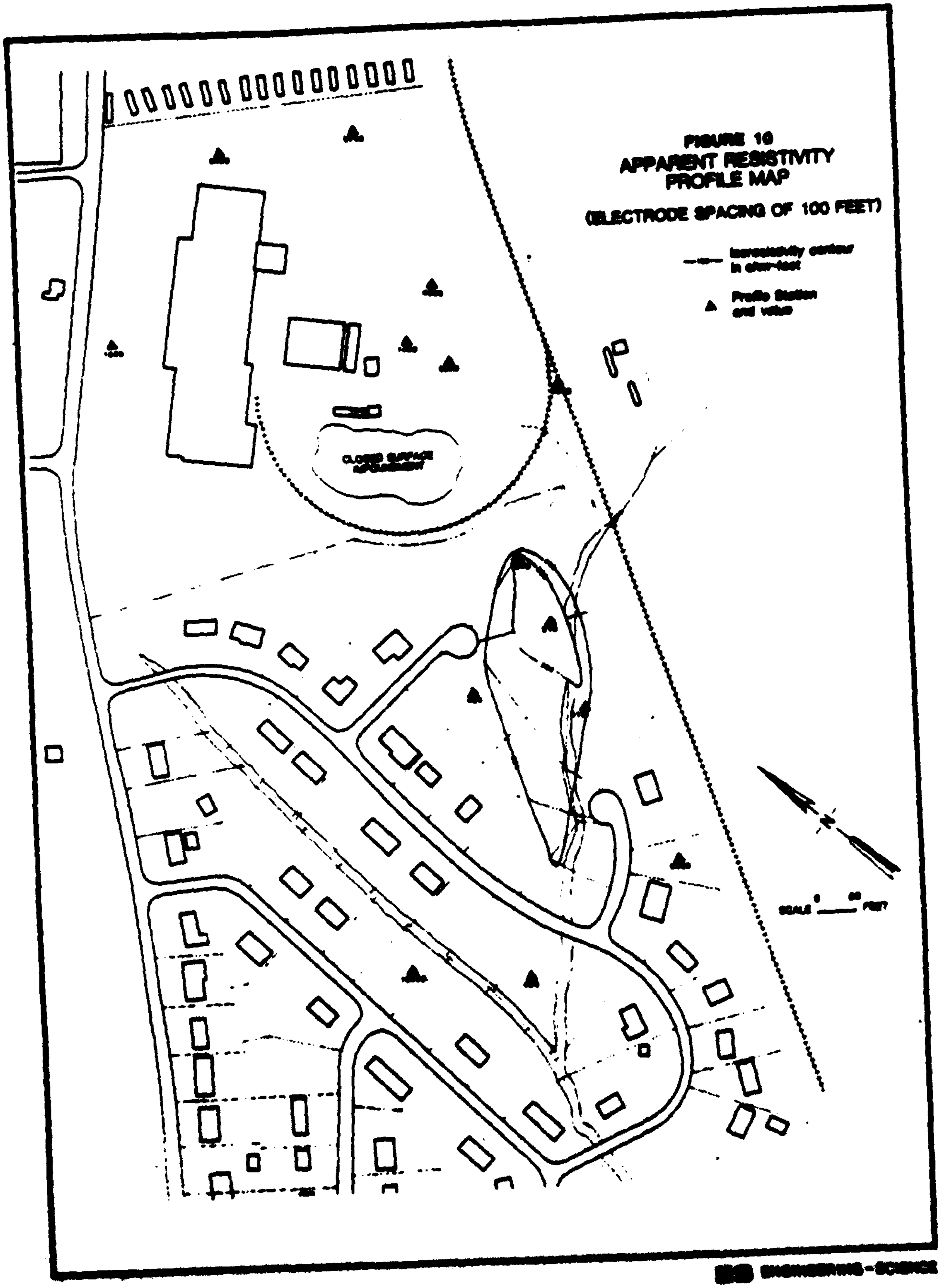


FIGURE 10
APPARENT RESISTIVITY
PROFILE MAP
(ELECTRODE SPACING OF 100 FEET)

whenever the utilization can be effective. The authors recommend that soundings be conducted in the suspected upgradient direction, on site and in the suspected downgradient direction. Interpretations should be correlated with available geologic data and the relative resistivity values of the soundings should be compared to determine if an anomaly can be identified and mapped by the profile technique. If the anomaly can be mapped, then a complete ER survey (additional soundings and profiles) should be conducted. A complete ER survey should not be conducted if the resistivity data results will not yield significant findings to advance the Phase II investigation.

Electrical resistivity, as with all geophysical techniques, should be confirmed by actual drilling and ground-water sampling, but knowing where to drill and how deep to sample are two very important factors that can save time and money as well as improve the professionalism of the investigation.

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THE HAZARDOUS MATERIALS TECHNICAL CENTER

David A. Appler
Defense Logistics Agency
Cameron Station, Viriginia

Murray J. Brown
U.S. Army Environmental Hygiene Agency
Edgewood, Maryland

Torsten Rothman, P.E.
Dynamac Corporation
Rockville, Maryland

INTRODUCTION

The Hazardous Materials Technical Center (HMTC) was established in June 1982 by the Defense Logistics Agency (DLA) to provide a center of expertise on technology and regulations related to handling, storage, transportation and disposal of hazardous materials. The need for an HMTC began with the assignment of responsibility to DLA for managing most of the hazardous wastes in the Department of Defense, (DOD). To help in carrying out this responsibility DLA decided to establish a contractor operated Hazardous Materials Technical Center. Through competitive procurement the Dynamac Corporation of Rockville, Maryland was selected to establish and operate this Center.

This presentation discusses the purpose, functions, and operating experience of the HMTC. The HMTC is an Information Analysis Center operated for DLA with technical supervision by the U.S. Army Environmental Hygiene Agency and DLA. The Center's logo is based on the Department of Transportation diamond-shaped hazardous substance warning symbol with a green diamond in the background symbolizing the HMTC's role in safety and protection of health and the environment.

The purpose of the HMTC is to provide a single location as a source for information on all aspects of hazardous materials technology and regulatory requirements. To develop this source HMTC will Identify, Collect, Assess, Synthesize, and Disseminate information on technology and regulations for the management of hazardous materials and wastes. This information will cover all aspects of hazardous materials/waste management and will come from a wide variety of sources. The data will be evaluated by the HMTC staff and the result disseminated in "user friendly" manner by the most appropriate means.

The initial users will be primarily DLA and the Military Services, with information provided to other Federal, State and local government agencies and the commercial/industrial sector on a non-interference basis.

FUNCTIONS

The HMTC is organized along two functional lines: development of a variety of products and services, and the creation of the Disposal File for the Hazardous Materials Information System (HMIS). The first functional area, Products and Services, includes the development of a variety of technical written publications such as:

- Handbooks are general guidance documents on broad topics. Potential subjects are Disposal Technologies, and the Storage and Handling of Hazardous Materials.
- State-of-the-Art Reports (SOARs) are more specific and limited than handbooks and can be considered monographs targeted to an experienced technical audience. Some potential topics are Hazardous Waste Exchanges, and Monitoring Equipment for Hazardous Waste Disposal Sites.
- Critical Reviews/Technical Assessments are similar to State-of-the-Art Reports but even more specialized.

- The Newsletter, the HMTC UPDATE, is a quarterly publication containing articles on new technology and regulatory developments, a calendar of events, and other articles of interest to personnel engaged in any aspect of hazardous materials/waste management.

- Abstracts and Indices. HMTC compiles abstracts of all the pertinent literature added to the Center's repository and publishes the HMTC Abstract Bulletin on a quarterly basis. The HMTC also prepares an annual index of all the abstracts published that year. The abstracts are sorted into twelve major index categories and retrievable using a specially-developed hierarchical keyword system.

- Bibliographic Searches. In addition to the HMTC database the Center has access to some 200 other computerized databases. A search begins with development of a search strategy designed to maximize retrieval of relevant material. The selected databases are searched and the identified abstracts reviewed to eliminate duplicates and obviously irrelevant material. The abstracts are then sorted alphabetically by senior author and bound into a booklet for delivery to the client. Typical subjects for bibliographic searches have included environmental and health effects, treatment of hazardous wastes, and toxicity data.

Another service of HMTC is the response to technical inquiries. The inquiries are received by phone or mail, and assigned to a technical staff member for preparation of the response. They are also included in the HMTC user analysis program. One purpose of the latter is to identify common areas of concern for early action. Each response also is abstracted and included in the HMTC database. Typical subjects for technical inquiries include disposal technology, regulatory requirements, product composition, and safety and health procedures.

In the special studies category, HMTC has performed a variety of projects including system safety studies of storage facilities, engineering evaluations of disposal technologies, development of remedial action specifications for hazardous waste disposal sites, and hazardous waste management surveys. We also provide support to the National Library of Medicine development of the Toxicology Date Bank. In the performance of special studies, we draw upon not only the HMTC full-time staff but also on the multidisciplinary and highly-experienced science and engineering staff of the entire Dynamac Corporation.

The Dynamac in-house computer resources are used to perform the cataloging, storage, and management of the information used in preparing technical inquiry responses, disposal data, and the various publications. Current plans are to have a hazardous substances regulatory database and the HMIS available as on-line systems in the near future.

The other major function of the HMTC is the development of a disposal file for the Hazardous Materials Information System (HMIS). The HMIS is a computerized database set up in 1978 by DLA to provide an organized repository for the information on the Material Safety Data Sheets (MSDSs) received from the suppliers of materials. The HMIS is also intended to assist in achieving compliance with pertinent regulations in the areas of safety, health, and transportation by making the necessary information readity available to persons in these areas.

The data files and the data elements currently in HMIS are described in the following overview, setting the stage for discussion of the data elements for the Disposal File.

The HMIS currently has two data files:

- o <u>Safety and Health File</u> - for which the information comes primarily from the Material Safety Data Sheets (MSDSs).
- o <u>Transportation File</u> - for which the information is prepared by the person developing the data for the HMIS based on the MSDSs and other data.

The information for third file containing disposal information, is being developed by the HMTC in close coordination with the users of the HMIS.

The Safety and Health File is comprised of five major sections: Identification and Logistical Data; Chemical Composition and Physical Properties Data; Safety and Health Information; Storage, Spill, Leak, and Disposal Procedures Data; and Supplemental Safety and Health Data. The Identification and Logistical Data section contains key items for the product, such as National or Local Stock Number, Federal Supply Code for Manufacturers, NIOSH Code, and Focal Point Indicator, which are unique to the product and may serve as links to the other files (Transportation and Disposal). These data elements also serve as a basis for retrieving information from the Safety and Health File.

The Chemical Composition and Physical Properties section contains information about the chemical components and the physical and chemical properties of the material, such as pH, boiling point, vapor pressure, solubility, and flash point.

The Safety and Health Information section contains information on such items as explosive concentrations, threshold limit value (TLV), first aid procedures, hazardous decomposition products, and protective equipment.

The Storage, Spill, Leak, and Disposal Procedures section provides the user of the product with guidance on appropriate action to take in storing the product, and how to handle a spill of the product, and in what manner the contained, spilled, or leaked material should be disposed. The waste disposal referred to here is for materials used to clean up spills and is very general in nature. A typical instruction is "Place material in suitable container for shipment to disposal area." Obviously, this is not enough to insure compliance with regulatory requirements for routine hazardous materials waste disposal. The Supplemental section is used for information which exceeds the capacity of the data elements in the other sections.

Similarly, the Transportation File has an Identification and Logistical set of data elements in addition to Transportation and Supplemental data elements. The Identification and Logistical data in the Transportation File serve the same purpose as those data in the Safety and Health File. However, the Transportation data pertains exclusively to the manner in which hazardous materials are shipped. Beginning with the product measurement data and special chemical classes in regard to shipping and ending with the different avenues of shipment (road, water, or air), the transportation data provides the user with a comprehensive source of information. This information is used to determine transportation restrictions, shipping modes, packaging, and labeling and manifesting requirements. The Supplemental section in the Transportation File serves the same purpose as in the Safety and Health File.

The final data file is the Disposal File which is being developed by the HMTC in close coordination with the organizations expected to be using the File and based on their experience.

It is proposed that five major sections of data elements will comprise the Disposal File. These sections include:

- General Information
- Disposal Data Elements
- Waste Manifest Data Elements
- Handling/Storage Data Elements
- Supplemental Disposal File Data

The General Information section is comprised partly of those data elements found in the Identification and Logistical data sections of the existing Safety and Health and Transportation files.

There are also several new data elements in this file. For the purposes of this discussion, only the significant new data elements are presented for consideration. These data elements are focused on DOD's needs and not all entries will be of interest or use to the non-DOD community, especially in the General Information section. However, some information even in that section and most of the information in the others, are of common interest.

General Information (new data elements)

- Accountability Acceptance by Defense Property Disposal Office (DPDO) - DOD policy has established eight categories of hazardous materials, such as biological/chemical warfare agents, unique R&D wastes, and municipal wastewater sludges that are not to be reported to a DPDO for disposal. DOD policy is that these materials will be the responsibility of the generator of the material. This first new data element would indicate whether or not the material is in any of those excluded categories and would therefore ensure uniform application, worldwide, of this policy.

- DPDO Disposal Assistance Service - indicates those items for which a DPDO will provide disposal assistance even though not required to formally accept the item, i.e., a DPDO might set up a service contract to dispose of industrial sludges.

- Environmental Impact Statement/Environmental Assessment Availability - indicates whether a National Environmental Policy Act document has been prepared on the disposal of this substance and where copies of this document are available.

Next, the Disposal Data elements appear, which are the key items of the HMIS Disposal File. They indicate the appropriate EPA Hazardous Waste Code under RCRA, the hazardous characteristic(s), and whether any or all parts of the DOD disposal cycle can be bypassed. These elements will provide complete technical instructions and recommendations for disposal of the material, supported by a technical handbook which allows the presentation of detailed information.

- DOT Hazard Class - contains the proper hazard waste class for shipment of hazardous waste.

- UN/NA Number - provides either the United Nations Number appropriate for international and domestic shipments or the NA number for items not recognized for international shipment (except to or from Canada).

- DOT Waste Label, - indicates the type of label specified for the item as a waste.

- Reportable Quantity - indicates if the package quantity is large enough to be considered a "Reportable Quantity."

The next group of data elements are designed to provide information on special handling and storage requirements or precautions relevant to the hazardous material. Although some of this information may duplicate data already in the Safety and Health or Transportation Files, an expanded input will provide more specific information to meet the regulatory requirements of DOT and EPA.

Handling/Storage Data Elements

- Handling/Storage Precautions/Materials To Avoid. Indicates specific handling/storage requirements or precautions relevant to the hazardous characteristics of the material. For example exposure to heat/cold/water or dryness or just simple aging could change the properties of certain materials and make them more hazardous.

- HMIS Storage Compatibility Code. Indicates storage compatibility codes as defined in the HMIS Procedures Manual, DOD 6050.5-M.

- Spill and Leak Control. Contains emergency procedures for control of a spill or leak.

The Supplemental Disposal File data elements will provide a place to list any unique data relevant to disposal of the item, as well as providing additional explanatory data relative to other data elements.

Although the data elements proposed for the Disposal File appear primarily administrative and logistical in nature, they are synthesized from extensive scientific and technical information on the hazardous materials to ensure that the procedures recommended are technically sound, meet all environmental and health regulations, and are implementable.

For example, the following factors are considered in the development of these data elements:

- o Potential degradation due to long term storage, e.g., picric acid will produce explosive crystals upon aging
- o Environmental transport mechanisms and environmental fate determined by the chemical/physical properties of the material and specific site characteristics
- o Treatment technology evolutions such as biodegradation, micro-orga ism acclimatization, chemical neutralization, fixation and solidification, slow and rapid oxidation
- o Industrial hygiene and engineering control technology as parts of a safety and health program for disposal workers

The development of special products by the HMTC is the next topic to be addressed in this paper. The HMTC contract contains an income objective provision which permits the addition of new tasks, related to the management of hazardous materials or wastes, in a relatively short time period. The special product development begins with discussion between customer and HMTC staff to establish a thorough understanding of the customer needs. HMTC staff then prepares a detailed work plan containing the technical approach, time schedule, cost estimate and categories of personnel to be used on the project. After approval of the work plan, the customer transfers the funds to DLA and the project begins. After some paperwork is completed to establish the initial mechanism, any new task can be underway in about two weeks after discussions begin between the customer and HMTC.

Most of the discussion in this presentation center on the activities of the Technical Operations/HMIS Group. This group consists of engineers, chemists, biologists, toxicologists, and many other scientific and technical specialists drawn from across the Dynamac Corporation as necessary. Supporting this group is the Information Support Systems Group which operates the computer and the HMTC repository and is composed of a staff of computer programmers, data entry personnel, a librarian, and research assistants. The Center also has a User Relations Group whose main function is to identify user needs to assist in refining the HMTC products and services. The Publications Group also publicizes HMTC through a periodic newsletter, brochures and news releases. This group produces two periodicals, the HMTC UPDATE (a quarterly newsletter), and the HMTC Abstract Bulletin. It also provides editorial review for all reports and other documents prepared by HMTC.

The HMTC is physically located in The Dynamac Building at 11140 Rockville Pike, Rockville, Maryland.

Mail should be sent to:

Hazardous Materials Technical Center
P.O. Box 8168
Rockville, Maryland 20856-8168

HMTC also has dedicated phone lines for easy access. From anywhere in the United States, including Alaska and Hawaii (but not Maryland), you can reach HMTC via (800) 638-8958. In Maryland call (301) 468-8858. HMTC can also be reached via the FTS on (202) 468-8858. Since HMTC is not an emergency response center, the phone lines are staffed only during normal Eastern Time Zone business hours, i.e., 8 am to 5.30 pm, Monday through Friday. During other hours your message will be recorded, and your call returned the next business day.

In conclusion, HMTC is a center of technical and regulatory expertise serving primarily DLA and DOD with publications and services, and these are provided to others on a noninterference basis. We will be working closely with all potential users to ensure those products and services meet the user needs.

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COMMUNITY RELATIONS ACTIVITIES AT DEPARTMENT OF DEFENSE SITES

BY

DAPHNE GEMMILL
SUPERFUND COMMUNITY RELATIONS COORDINATOR
U.S. ENVIRONMENTAL PROTECTION AGENCY
401 M STREET, S.W.
WASHINGTON, D.C. 20024

and

MARY D. SEXTON
SPECIAL CONSULTANT/PROJECT MANAGER
ICF INCORPORATED
1850 K STREET, N.W., SUITE 950
WASHINGTON, D.C. 20006

COMMUNITY RELATIONS ACTIVITIES AT DEPARTMENT OF DEFENSE SITES

By

Daphne Gemmill, U.S. Environmental Protection Agency
and
Mary D. Sexton, ICF Incorporated [1]

Community relations activities during hazardous waste site cleanups are important for several reasons. Through these activities, the response agency can provide citizens affected by the site with needed information about site contamination and the likely effects of cleanup actions. Citizens in turn can provide the response agency with needed information about the extent of contamination, about alternative response actions, and about responsible parties. And, a close working relationship between the response agency and the community can help ensure that the community will support a cost-effective remedy at the site. This paper describes what the Environmental Protection Agency (EPA) has learned about effective community relations activities at hazardous waste sites and suggests how some aspects of EPA's approach to community relations may be applicable to Department of Defense (DOD) sites.

EPA'S COMMUNITY RELATIONS EXPERIENCE

During the first three years of the Superfund program, EPA has found that a good community relations program at hazardous waste sites requires substantially more than a public relations effort. For example, EPA has found that citizens do not always accept that the government has their best interests at heart just because the agency keeps them informed about the planned response actions. Instead, citizens have stressed that they want specific kinds of information about their site when they need it and in the form they need it. EPA has also learned that some citizens want more than information about the site and response action: they want an opportunity to be involved in response decisions.

Providing citizens with the information they need and involving them in response decisions is a resource-intensive effort that requires skill and commitment. For example, to identify the kinds of information citizens want about the site and the planned response action, agency staff must meet with citizens and ask: what information do you want about the site? in what form do you want it? when and where do you want to receive it? how can we accommodate your need for information if we cannot for some reason meet your specific requests?

Furthermore, citizen involvement in response decisions often requires

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[1] Daphne Gemmill is EPA Headquarters Superfund Community Relations Coordinator. Mary D. Sexton is a consultant and community relations project manager at ICF Incorporated.

substantially more than implementing a formal comment period on response decisions. It can mean meeting with citizens regularly during remedial planning to elicit and consider their concerns. It can involve keeping records of comments citizens make throughout a response action and then demonstrating how the agency considered these comments and factored them into response decisions. Or, citizen involvement may require eliciting citizen comments on procedures for implementing cost-effective alternatives and then implementing the community's preferred approach (such as complying with the community's wishes about the timing and route of transport of wastes off-site). In all cases, citizen involvement means giving citizens an opportunity to affect response planning and decisions.

EPA's recognition that community relations requires both an information program and an active citizen involvement program developed over a three year period. When the Superfund program was first implemented, EPA conducted an analysis of 21 hazardous waste sites to determine how community interests can affect response activities. Among other things, this analysis confirmed that:

- Every site has the potential for public opposition, heated conflict, and high media visibility;
- Public opposition to agency response plans can lead to delays, work stoppages, obstruction of technically sound remedies and cost overruns; and
- The technical adequacy of a response action in no way assures public acceptance.

In response to this analysis, EPA designed and implemented a community relations program for Superfund. Under this program, EPA staff in the Regional Offices were required to develop a community relations plan for each remedial and longer term removal site that detailed the two-way communications activities to be conducted at the site. The program also required that EPA hold a formal comment period prior to selecting a remedial alternative and give prior notification before taking response actions. About a year ago, after undertaking a program review and listening to public comment, EPA decided that its program was adequate as a public information program but inadequate as a citizen involvement program.

Since that time, EPA has modified its community relations policy, strengthened its commitment to involving citizens in response decisions, and initiated a training program for Regional Office and state staff to ensure that the policies are understood and carried out. EPA's current goal is to ensure that its Superfund community relations program is both a public information program and a public participation program. As Administrator William Ruckelshaus stated recently during a pilot training program: "The purposes of the program are to:

- Encourage -- actively -- citizens to express their concerns and provide information;

- Seek out -- actively -- citizen comments to all response actions;

- Consider -- explicitly -- citizen comments in formulating response decisions; and

- Explain -- specifically -- how citizen comments were incorporated into response decisions."

To ensure that the program's objectives are reflected in activities carried out at sites, EPA now requires that:

- Community relations plans be based upon discussions with state and local officials, civic and community organizations, interested residents, and media to gain a first hand understanding of the major community issues, citizens' information needs, and level of public interest.

- Community relations activities be closely integrated with technical response activities.

- A comment period be implemented before remedial decisions are made.

- Community input be solicited at other points during the response action as well, wherever feasible and needed.

- Response agency staff document how community input was considered and incorporated into response plans.

We bring this abbreviated history of EPA's community relations program to DOD's attention because we believe that DOD can benefit from EPA's "lessons learned" in designing its approach to community relations during response actions. Under the Memorandum of Understanding (MOU) between DOD and EPA for implementing the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, DOD is responsible for providing information to the local community when DOD has sole responsibility for the site and is jointly responsible for community relations activities with EPA where EPA and DOD share site responsibility. The MOU states that EPA and DOD must conduct response actions in accordance with the procedures established by the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). Section 300.61(c)(3) of the NCP requires that response agencies "be sensitive to local community concerns [in accordance with applicable guidance]."[8] As DOD

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[8] The NCP is currently being revised. EPA anticipates that the provisions regarding community relations activities will be strengthened.

explores what it means to be "sensitive to community concerns", it may wish to consider how the suggested program philosophy and activities outlined below can be tailored to the needs of its Installation Restoration Program.

SUGGESTED COMMUNITY RELATIONS PHILOSOPHY

EPA has found that there are a number of attitudes that are important for response staff to have and convey in carrying out a cleanup action:

- Consider the site's community relations program to be an integral part of the response effort. This requires building a close working relationship between technical response staff, public affairs staff, and any contractors supporting the Department's efforts.

- Recognize that citizen concerns are legitimate and that they need opportunities to express them and to have them considered seriously. Citizens living near DOD sites may believe that their health, their children's health, their water supplies, or their property values are threatened. In addition, they will have to live with the results of any response action long after the agency completes the action. Their concerns, therefore, should be addressed as early as possible in the response action.

- Be sensitive in your dealings with citizens. They are not adversaries. Particularly in any early meetings with citizens, make more of an effort to listen than to talk or explain the Department's position. Try to identify what citizens' real concerns (such as threats to health) are as opposed to their stated positions (such as demands for cleanup in a certain time period). Develop a communications program that responds to their real concerns.

- Acknowledge that citizens may provide the Department with valuable information. This information may take several forms: information about responsible parties; information about the extent of off-site contamination; information about health effects. Furthermore, some citizens may have a strong engineering or technical expertise that allows them to comment constructively on remedial alternatives being considered by the Department.

EPA has found that while this community relations philosophy appears to be straightforward, it is actually very difficult to implement and to do so consistently. DOD may encounter similar problems. For example, although DOD public affairs experts will probably be enthused about an active communications program, scientists and engineers working at the site may not be comfortable with the idea of meeting with citizens, answering their questions, and eliciting citizen input. In addition to sufficient resources allocated to community relations, two things are needed to make the philosophy work:

- Community relations training. Even if DOD's public affairs staff will have primary responsibility for conducting community relations activities at sites, DOD's technical response staff will also need to meet with citizens, participate in meetings, review citizen comments, consider how their input might affect response decisions, and help document how the Department responded to citizen input. To do these things well, most technical staff will require training in how to avoid conflict, in how to conduct and participate in effective meetings, in how to build good media relations, and in how to identify areas for citizen input.

- Top management commitment. Integrating community relations activities with the technical response program will not happen unless the Department's top management says that it must happen. With all of the pressing response efforts that go on at a hazardous waste site, community relations will always be given minimal attention unless the response program's top management emphasizes that it is a high priority.

SUGGESTED SITE ACTIVITIES

EPA's community relations program emphasizes that communications activities at Superfund sites should be tailored to the needs of the community. It includes, however, both required and highly recommended activities that were developed after an analysis of effective response actions across the country. DOD staff may wish to consult the guidelines for these activities that EPA has prepared for its staff with Superfund site responsibilities. [See U.S. Environmental Protection Agency, Community Relations in Superfund: A Handbook, September 1983.]

Based upon our assessment of those activities that have been most needed and useful at EPA sites, we suggest the following community relations activities for DOD's consideration. Again, because each site presents markedly different response and community relations problems, no one set of activities can be prescribed for all sites. We view the activities listed below as a model community relations program.

Activity 1: Conduct personal meetings with concerned citizens.

Before performing site work, DOD public affairs or technical staff (or both) can consider meeting with citizens affected by the site, local and state officials, and other concerned community members to identify their concerns. Experience has demonstrated the importance of early, personal contact between citizens and government response agencies. These meetings can be extremely useful for eliciting community input on the following:

- The level of public concern and the history of citizen involvement in seeking a solution to problems at the site;

- The types of information citizens would like to receive and the form in which they prefer to receive it (e.g., small group meetings, fact sheets, progress reports, news conferences);

- Citizens' perspectives on the history of the site and any potentially responsible parties of which they might be aware;

- The kinds of health and environmental problems citizens may have noticed that might have been caused by exposure to the substances found at the site;

- The existence of other citizens concerned about or having information about the site whom DOD should contact;

- Those elements of the response action of greatest interest to citizens; and

- The kinds of response actions citizens would like to see conducted.

<u>Activity 2</u>: <u>Prepare a communications plan for the site</u>

A community relations plan, based upon discussions with interested members of the community, can be a useful document for: detailing the Department's understanding of the major community issues; explaining how the Department will provide information and elicit citizen input; providing a schedule of communications activities; and listing DOD staff that citizens can contact with questions. This plan can be provided to or made available to interested members of the community.

Such a plan serves many useful purposes. It forces staff to identify major community concerns and think through how the agency will respond to them. It requires staff to identify points of community input and to make these known to the community. It is a good management tool for tracking program accomplishments. And, it demonstrates to the community that the Department is serious about its commitment to provide it with information and to provide it with opportunities for comment.

The plan obviously does not ensure that a good community relations program will be conducted at the site. But, without a plan, it is unlikely that a program that meets citizens' needs will be implemented.

Activity 3: Implement a formal comment period prior to selecting the cleanup option

A formal comment period on the proposed remedial alternative is a good way to ensure that community views on DOD response actions are elicited. In addition, it would allow DOD to meet the National Environmental Policy Act's requirements for public participation.

During any comment period implemented by DOD on proposed response actions, DOD might find it advisable to conduct small group meetings or workshops to explain the results of its remedial studies. Prior to the close of the comment period, DOD might also wish to consider those areas where it has some flexibility in meeting citizen concerns and explore those areas with citizens. (For example, citizens might disagree with DOD's plan for the placement of site structures and DOD might be able to change its plans to accommodate citizen concerns.)

Activity 4: Establish an information repository

An information repository is a project file, located in a convenient location in the community that contains site information, investigatory reports, and other documents on site activities. It is being used as an effective information provision technique during a number of Superfund response actions such as the response at the New Bedford, Massachusetts site. The Acushnet River in New Bedford, Massachusetts has become contaminated with PCBs and heavy metals, forcing a ban on commercial and subsistence fishing and lobstering. Among the techniques that EPA is using to provide information to the local community is an information repository located in town halls and libraries in New Bedford and neighboring Fairhaven. EPA is including in the file information about PCBs, the known sources of the contamination, the most affected areas, and the schedule of site activities. Both technical documents and non-technical explanations of the documents are placed in the file.

Activity #5: Conduct small group meetings and workshops

EPA has learned from experience at a number of sites that large public meetings and formal hearings, traditionally the centerpiece of a public participation program, are often inappropriate vehicles for communicating information about response actions and for obtaining citizen input. Large public meetings can also exacerbate any existing adversarial relationships between citizens and the government, and prevent constructive discussions.

Small group meetings and workshops can be effective communications tools at sites in the following kinds of situations:

- DOD believes that citizen interest in the planned response action is high and citizens may desire a substantial amount of input into the response action and a substantial amount of interaction with Department staff.

- The release caused (or is perceived to have caused) a number of health problems for residents near the site and these individuals need to receive detailed information and explanations of health studies.

- DOD's relationship with the community has not been good up to this point for any number of reasons and a closer working relationship with affected citizens would improve trust and cooperation.

- DOD has sufficient resources available to plan and conduct a series of informal meetings and workshops that are ultimately available to all interested citizens.

EPA has given considerable thought to how to plan and conduct small group meetings and workshops and can provide this information to DOD's community relations staff.

Activity #6: Provide progress reports

Progress reports are brief fact sheets describing past site work and the latest developments occurring during the response. They are more detailed than news releases and less detailed that background papers. Their target audience should include local officials, citizen leaders, civic and community organizations, and the media covering the site. For example, a progress report may contain information such as: the types and quantities of substances known to be at the site; the known extent of contamination; a brief explanation of ongoing activities; DOD's response plans over the next few months; and DOD contact staff. Progress reports can either be issued on a regular basis (say every month) or whenever important developments occur during a response (for example, the conclusion of a phase of the DOD response action).

Activity #7: Call or meet with citizen leaders frequently to inform them of progress

EPA has found that consistent, personal contact with citizens is the most important determinant of a successful community relations program. While frequent contact is resource-intensive in the short run, it is extremely cost-effective in the long run. There is no better way to demonstrate the Department's commitment to keeping the community informed and to eliciting its views.

SUMMARY

This paper has highlighted an approach to community relations activities at hazardous waste sites that has worked for EPA and may work for the DOD as well. This approach is based on the premise that citizens not only need information about hazardous substance response actions but also have the right to be involved in response decisions. It is an approach that is mutually beneficial to the community and to the government response agency. Under the program outlined above, citizens receive the information they need and have an opportunity to affect response decisions. The government agency in turn often receives needed information from citizens, gains community support for an efficient response action, and avoids counter-productive disagreements.

AD-P004 151

PROTOCOL FOR AQUIFER CLEANUP DECISION MAKING AT MILITARY INSTALLATIONS

by

Robert C. Knox

and

Larry W. Canter

Environmental and Ground Water Institute

and

National Center for Ground Water Research

University of Oklahoma

INTRODUCTION

Activities of the U.S. Army at ammunition plants, depots, and arsenals involve the handling and appropriate disposal of a variety of materials identified as potentially toxic or hazardous to human health and the environment. Section 3001 of the Resource Conservation and Recovery Act of 1976 defines hazardous wastes as:

> "...a solid waste, or combination of solid wastes, which because of its quantity, concentration, or physical, chemical, or infectious characteristics may --
>
> a. cause, or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapaciting reversible, illness; or
>
> b. pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed."

Hazardous wastes are of concern since they may be lethal, nondegradable, persistent in nature, and/or biologically magnified. Planned and unplanned discharges of hazardous wastes can lead to soil contamination and, possibly, surface and ground water contamination as a result of surface runoff and subsurface transport. Soil contamination has occurred in the vicinity of planned landfills and liquid waste holding ponds which are located in permeable soils or improperly lined. Unplanned discharges can occur as a result of accidental spills, and soils in spill areas have also been contaminated.

MAGNITUDE OF PROBLEM

A study to determine the magnitude and scope of military hazardous waste problems and to identify and assess the Department of Defense (DOD) hazardous waste management approach and future needs has been conducted (Kawaoka, et al., 1981). The study approach was designed to survey current activities of DOD agencies involved with hazardous waste management operations and associated research and development activities. Discussions were held with DOD policymakers, command and field managers, and technical experts to determine what they perceived as critical areas and appropriate management strategies. Regulatory issues and current research activities were discussed with U.S. Environmental Protection Agency (EPA) officials. These discussions were supplemented by a review of pertinent reports, memoranda, and regulations. The magnitude of the problem is illustrated by the fact that 911 installations are in the process of being checked for hazardous waste sites, and as many as 200 may require some type of cleanup action. The following United Press International story (August 11, 1983) illustrates the national concerns related to this problem:

The Pentagon, with its most exensive programs already under way, still expects to spend about $500 million to finish cleaning hazardous waste sites at military installations, a defense official says.

Lt. Col. Peter Daley, director of environmental policy for the department, said Wednesday the Defense Department has been working since 1980 to locate hazardous waste sites on all defense lands.

The program involves 911 installations, but only 130 locations remain to be checked, Daley told the investigations subcommittee of the House Public Works Committee.

Daley estimated that as many as 200 installations require some cleanup actions, but only 18 are completed or under way.

Of those remaining, he said, "We don't know of any cases where immediate health or environmental threats exist. In addition, the great majority of the cleanup actions we will face are relatively small scale.

"Most of the few big, costly programs are under way," he said, adding that the median costs of the first few cleanup projects has been about $1 million, but the cost is expected to drop for the later, smaller projects.

"The bottom line is that it's going to cost about a half a billion dollars to complete the cleanup task," Daley said.

Subcommittee Chairman Elliott Levitas, D-Ga., noted reports of disagreement and lack of cooperation between the Defense Department and the Environmental Protection Agency, which has the major role in hazardous waste control.

The $1.6 billion Superfund authorized by Congress to pay for hazardous waste cleanup operations is not available to government agencies and Daley noted the cleanup funds for military sites will come from the services operations and maintenance accounts.

Daley said the Pentagon and the EPA reached agreement Tuesday on a memorandum of understanding that outlines how the two agencies will work together in cleaning up waste sites at military installations.

He stressed that the EPA and state and local officials are given all information about such sites "as soon as we are sure it is technically accurate."

Levitas said the federal government, particularly the Pentagon, "must be an example for the nation on how to handle these (hazardous waste) problems."

Rep. Guy Molinari, R-N.Y., said the Defense Department is "probably the greatest generator of hazardous wastes among all federal agencies."

The Department of Defense (DOD) has developed a program to identify and evaluate past hazardous material sites on DOD property, to control the migration of hazardous contaminants, and to control hazards to health or welfare that may result from these past disposal operations. This program is called the Installation Restoration Program (IRP). The IRP is a four-phase program consisting of: Phase I, Initial Assessment/Records Search; Phase II, Problem Confirmation; Phase III, Technology Base Development; and Phase IV, Operations. The U.S. Army through the Toxic and Hazardous Materials Agency (USATHAMA) has conducted a number of Phase I studies at Army installations, with several locations proceeding to subsequent phases depending upon the Phase I findings.

There are multiple potential sources of hazardous wastes handled or generated at U.S. Army installations. The multiplicity of sources can be illustrated by two studies conducted by the Construction Engineering Research Laboratory (Messenger, et al., 1983; and Kraybill, Mullen and Donahue, 1980). The *first* study investigated the feasibility of tracking hazardous materials through procurement, distribution, use, collection, and disposal at U.S. Army fixed facilities (Messenger, et al., 1983). It was found that a complete tracking system would require major changes to materials distribution and accountability procedures. Implementing complete tracking procedures would be very costly at military installations because of the great diversity of hazardous materials procured and the large numbers of activities which use them. Another tracking system investigated was the monitoring of procurement data. This type of system has been used successfully at two installations and it was recommended that it be tried at others on an experimental basis.

The second CERL study examined hazardous waste production at two military installations and a major Army hospital (Kraybill, Mullen and Donahue, 1980). Six major hazardous wastes were found: (1) waste oil/petroleum oil lubricant (POL) products; (2) solvent tank bottom sludges; (3) paint wastes; (4) pesticides and insecticides; (5) PCBs; and (6) medical/infectious wastes.

RELEVANT RESEARCH

A number of U.S. Army research activities have been recently conducted on the general issue of hazardous waste management and disposal, and several illustrations will be cited. Brown (1977) presented a methodology that can assist the Army in allocating resources among candidate research and development studies on the environmental effects of Army chemicals, in a cost-effective manner with respect to the development of criteria for standards. The basis of the methodology is a mathematical model of the process leading from the initial pollution of air, water, or land to the eventual environmental effects of the chemicals in question. The model estimates a total hazard value, weighted among human and ecological effects, with a corresponding uncertainty due to lack of knowledge. The allocation methodology then compares the reduction in hazard uncertainty expected to be achieved after a research study with the cost of the study, and ranks candidate studies according to the ratio.

Mikucki, et al. (1981) conducted a study of the characteristics, control and treatment of leachate at military installations. The study report documents the results of an extensive review of literature on leachate, provides introductory information about leachate, and answers such questions as: what is leachate; why is it important; what are its characteristics; how can a leaching landfill be detected; how can leachate formation be mitigated; and what does remedial action cost. The report is intended to educate Army personnel about leachate, provide DA points of contact for assistance, and provide guidelines for problem identification. This report may be used by Facilities Engineers to identify leaching landfills, prepare and implement a monitoring program, and institute short-term remedial measures.

Two specific studies have been conducted on waste materials and soils (Houle and Long, 1980; and Kaplan and Kaplan, 1982). Houle and Long (1980) reported that a graded serial batch extraction method is useful for studying the leachability of industrial wastes and for determining the retention characteristics of soils. A correlation between waste and soil extraction volumes and the time of leaching in columns or in the field allows for the development of a technique for the accelerated testing of wastes and soils. The leachability of heavy metal-laden wastewaters was examined in this study through such batch tests.

Kaplan and Kaplan (1982) reported on a study of the biodegradability and mutagenicity of 2,4,6-trinitrotoluene-surfactant (TNT) complexes in soil and water. Soil leaching studies indicated that in situ immobilization of TNT is not feasible due to the large quantities of surfactant required and the inability of the surfactant treatment to immobilize TNT microbial reduction products. The Ames screening test for mutagenicity revealed that these complexes are a significant mutagenic hazard.

Finally, some research has been done on the fixation or control of hazardous waste migration in soil, and two examples will be cited (Rosencrance and Kulkarni, 1979; and Price and Sommerer, 1982). In the first study, electroplating waste samples from Tobyhanna Army Depot, PA, and other synthetically prepared samples of hazardous waste were fixed by the WPC-VRS process of Werner and Pfleiderer Corp. (asphalt microencapsulation) and evaluated by using the modified Wisconsin leaching test (Rosencrance and Kulkarni, 1982). It was found that the process provides satisfactory attenuation to leaching of heavy metal ions, hexavalent chromium, and cyanide. The presence of complexing ions like cyanide, ammonia, and high pH, however, seems to adversely affect the performance of the process, slightly increasing the leaching of zinc, copper and cadmium. Excepting these metals, the concentrations of other metals in the leachates generated are within the limits set by the U.S. Environmental Protection Agency.

Price and Sommerer (1982) reviewed and evaluated information on compatibility and compatibility testing of liner/barrier materials with hazardous wastes. The emphasis of the study was on methods of long-term and accelerated compatibility testing and models to predict liner compatibility with various wastes. Very little information is available on long-term compatibility with various lining materials. Essentially no methods are available for predicting membrane liner compatibility with hazardous wastes.

For the past two years personnel at the National Center for Ground Water Research (NCGWR) have been collecting and analyzing information on various aquifer restoration technologies and previous application of ground water pollution cleanup measures. One result of this study is the development of a protocol or structured approach for selecting an optimum aquifer restoration strategy. With minor modifications, this protocol can be applied to DoD installations. The protocol represents an invaluable aid for conducting the first three phases of an Installation Restoration Program. The remainder of this paper outlines the major steps of the protocol.

REMEDIAL ACTION MASTER PLANS

The general approach to be taken in developing aquifer restoration schemes is, for the most part, intuitively obvious. A logical first step is a preliminary assessment of the nature of the problem. Based on the preliminary assessment, potential alternative remedial measures are identified. From the list of possible alternatives, an optimum would be selected through environmental impact risk assessment, and cost-effectiveness analyses. Implementation and construction of the chosen alternative would be next, followed by monitoring of the effectiveness of the measure.

A review of the literature shows the above to be the pattern used most frequently. Most of the work in developing structured approaches to solving ground water contamination problems has been associated with the Comprehensive Environmental Response, Compensation and Liability Act, P.L. 96-510 (known as CERCLA or Superfund). Specifically, Superfund sites require the development of a "remedial action master plan" or RAMP. The purpose of a RAMP is to identify the type, scope, sequence and schedule of remedial projects which may be appropriate (Kaschak and Nadeau, 1982). Figures 1 and 2 are attempts to represent the RAMP process in the form of flow charts. Additionally, Table 1 lists the phases of a site contamination and liability audit. Two

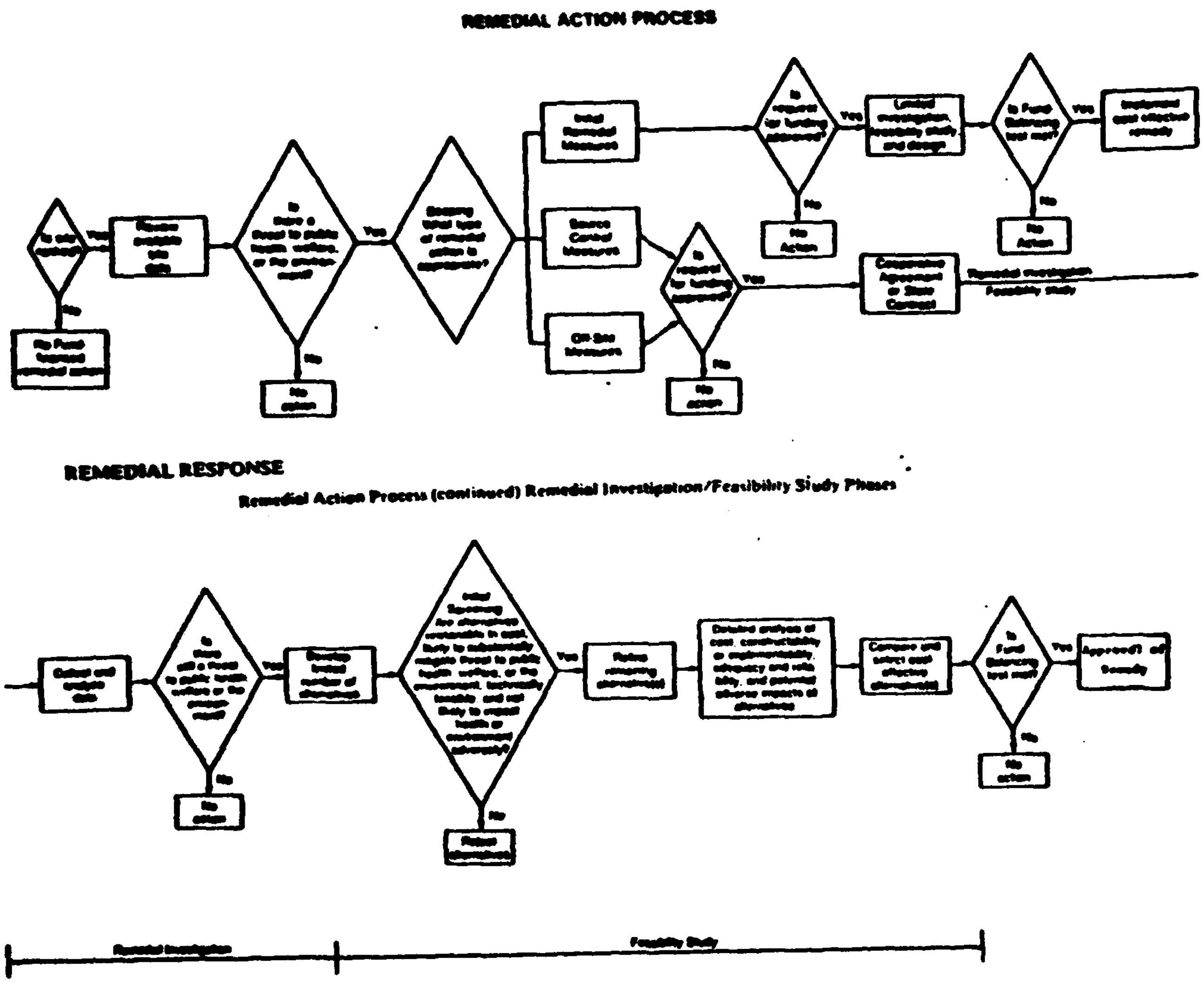

Figure 1: Remedial Action Process (Bixler, Hanson and Langner, 1982)

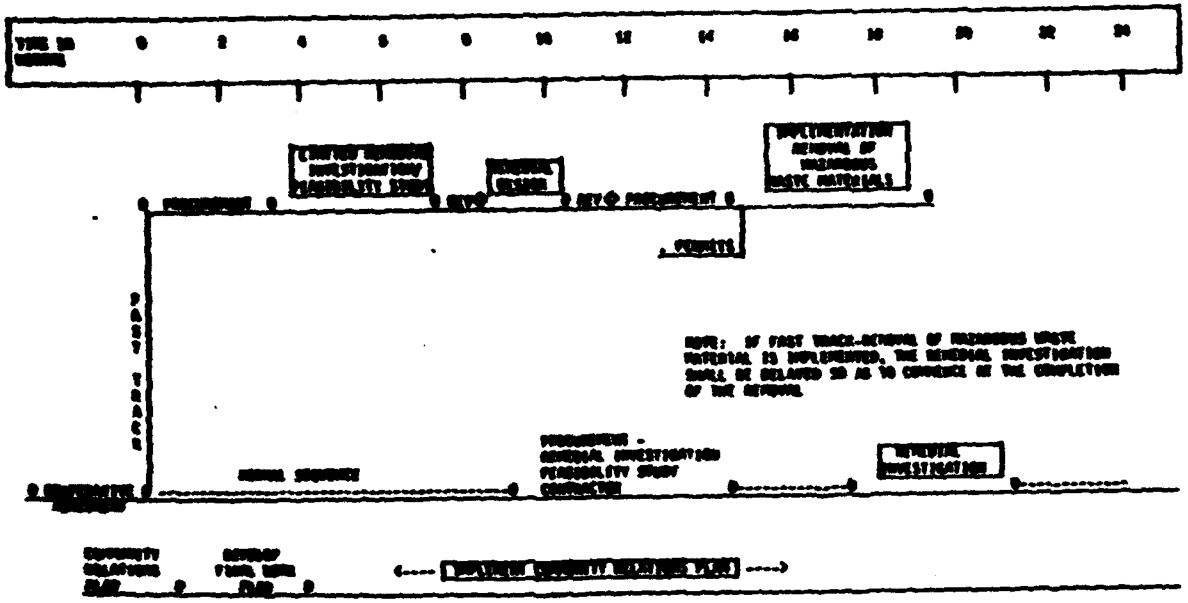

Figure 2: Master Site Schedule (Kaschak and Nadeau, 1982)

Table 1: Site Contamination and Liability Audit Phased Structure

Screening	Phase 1	Initial Property Inventory
Phases	Phase 2	Classification and Identification Problem Properties
	Phase 3	Preliminary Field Screening
	Phase 4	Prioritization of Problem Properties
Emergency Action Phase	Phase 5	Immediate Emergency Stop Action Response
Detailed Site	Phase 6	Detailed Site Field Investigation
Investigation and Remedial	Phase 7	Definition of Remedial Strategies, Risk and Financial Liability Assessment and Remedial Cost Effectiveness
Phases	Phase 8	Selection of Preferred Remedial Strategy
	Phase 9	Implementation of Remedial Action
	Phase 10	Certification of Performance and Addressing Future Potential Liability Issues

Housman, Brandwein and Unites (1981)

features are common to all three of these outlines. First, they all follow the general intuitive outline presented above. Second, they all have provisions for immediate remedial action to buy time while long term solutions are developed. Kaschak and Nadeau (1982) emphasize the importance of a RAMP as the first step in any remedial program.

The RAMP is designed as an approach for developing an optimal solution. Incorporated within the RAMP is the analysis of alternative remedial measures in order to decide on an optimum strategy. The analysis involves three different aspects: 1) environmental impact; 2) cost; and 3) risk. Risk assessment is an area of study that is now receiving increased attention. Berger (1982) states that risk assessment has been defined as, "the identification of hazards, the allocation of cause, the estimation of probability that harm will result, and the balancing of harm with benefit." Berger (1982) goes on to develop a general risk assessment methodology based on four factors; receptors, pathways, waste characteristics, and waste management practices. Dawson and Sanning (1982) have developed a risk assessment model based on the exposure-response approach. Kes and Shih (1982) describe a technique for determining risk acceptability. The main problem faced by all risk assessment techniques is that a large portion of the needed information, such as risk pathways or acceptable concentrations, is unknown.

Because ground water cleanup activities are, in general, expensive, interest in analyzing the costs of these activities is high. St. Clair, McCloskey and Sherman (1982) discuss the advantages and disadvantages of risk assessment, cost/benefit analysis, cost-effectiveness analysis, decision-tree analysis, trade-off matrices, and sensitivity analysis for alternatives evaluation. Using certain elements of these techniques they have developed a framework for evaluating cost-effectiveness of remedial actions. Evans, Benson and Rizzo (1982) describe an integrated, three-phased approach for cost-effective preliminary assessments at hazardous waste sites.

There are two points to be noted about the studies discussed above. First, they have all been directed toward uncontrolled hazardous waste sites. Second, they have the inherent assumption that a list of alternative measures exists or can be generated. Little information can be found pertaining to ground water pollution episodes away from hazardous waste sites or on the actual development of alternative remedial measures. Unterburg, Stone and Tafuri (1981) discuss a system for developing alternative remedial measures for spills of hazardous chemicals. Caldwell, Barrett and Chang (1981) discuss a hazard ranking system, but this is applied to different sites rather than different measures at an individual site. Dawson and Brown (1981) have developed an integrated site restoration process, as outlined in Figure 3, but this also glosses over the actual development of alternatives.

The remainder of this report will discuss the step-by-step procedure that can be followed to develop aquifer restoration schemes.

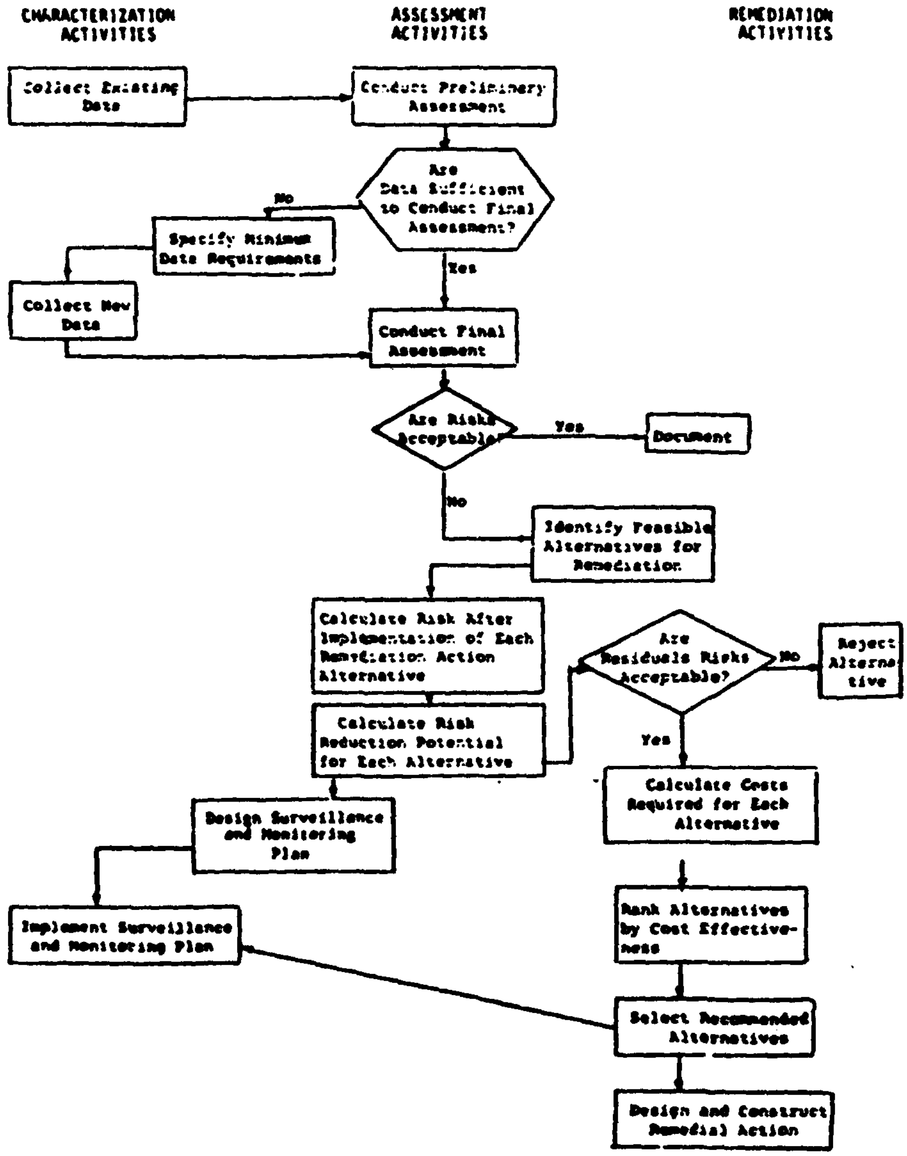

Figure 3: The Integrated Site Restoration Process (Dawson and Brown, 1981)

This procedure is developed in a general fashion so as to be applicable to sites other than uncontrolled hazardous waste dumps. Additionally, emphasis is placed on the procedure for developing the list of actual, technical alternatives.

Multi-Disciplinary Team

Ground water pollution is not strictly a hydrogeological problem. The development of a ground water pollution clean up approach requires involvement from a number of different disciplines. Managerial personnel will be involved in the overall planning and development of the project. Technical personnel, both on-site and off-site, will aid in the design of the remedial measure. Remedial-related personnel from the construction industry will have involvement. Also, institutional personnel from different levels of government will almost invariably be involved. Within each group, a number of different disciplines might be required. For example, the technical personnel required could include hydrogeologists, engineers, soil scientists, chemists, and even toxicologists, to name a few. The bottom line is that the solution will require a multi-disciplinary approach involving a multi-disciplinary team. Carefully assembling a multi-disciplinary team should be the first step in any aquifer restoration effort.

Problem Definition and Characterization

The obvious next step in actually dealing with a ground water pollution problem is to define and characterize the problem. The problem will need to be defined in terms of its temporal and areal release patterns and its urgency for a solution. The two temporal categories are "anticipated problems" and "existing problems". Anticipated problems most usually will be planned future facilities that will have the potential to threaten ground water supplies. This situation is more desirable in that the engineer or planner is one step up because the pollution or polluting activity has yet to occur. The other type of problem is the existing problem. This is the situation where a facility or activity with ground water threatening potential is already in effect. The existing problems can further be broken down into those that have already degraded the ground water and those that have not yet disrupted the ground water but are expected to do so. Actually, the steps to be taken in identifying potential solutions to either of the two types of problems are similar, but because of their "temporal" differences the proposed solutions can differ significantly.

1. Anticipated Problems

Having identified an anticipated problem, the next step is to identify the areal release characteristics, the duration, and the urgency of the problem, if possible. The release characteristics of the problem will be directly related to the source. The source, could be a point source (disposal well), an area source (fertilizers in agriculture), a line source (highway deicing salts), or even a regional source (increasing number of septic tanks in a region).

The duration of the problem can be classified as either acute or chronic. Will the anticipated problem be short term such as lowering of water levels due to construction dewatering or will it be a long term problem that will require long term solutions such as a series of injection wells to prevent salt water intrusion?

The urgency of the problem will be a function of the potential contaminant(s) and the importance of the threatened aquifer. Anticipated problems usually will have no urgent need for a solution. The ground water pollution potential can be circumvented by incorporating certain controls in the design stage.

2. Existing Problems

With existing pollution problems the information needed to characterize it is straightforward. Having identified the problem, the next step is to identify the source if possible. The contaminant release characteristics and duration of the problem will fall into one of the classes outlined above. However, the urgency for a solution can sometimes be the critical factor with an existing problem. If the polluted aquifer is a source of drinking water or the problem was discovered due to an adverse public health reaction, there may be a need for an immediate (if only temporary) solution.

A general description of the problem is necessary for defining the scope and extent of further studies and ultimate remedial actions. For example, if a hazardous substance is detected in a water supply well, the immediate solution may be to provide an alternative supply of water. This temporary measure may buy some time for study and development of a more permanent solution.

Preliminary Study

After identifying an existing or potential ground water threatening activity or facility, the next step is information gathering and problem characterization. The detail and duration of this step will be determined by the urgency of the problem and funds available.

The areas of information listed below are designed to be comprehensive, but they are described in general terms with few specifics. Not all areas will pertain to every problem. Probably the most useful function of these lists will be to aid in generating a list of needed information for specific problems.

It should be emphasized that the lists below are not in any particular order although some of the steps are dependent on the others. Probably the area that needs to be considered prior to initiation of any detailed study would be that of funding. Once funding has been determined, the scope of the analysis can then be delineated. The other areas of information should probably be approached in groups such as problem specific information (A, B), site specific information (C, D, F), and others (E, G).

Should it be decided to go into more than just a cursory review of the problem, sources of information may become a question. Some of the agencies identified in step G most probably will have some information. Listed in Table 2 are some other possible sources of information as related to the different groups. For information specific to the technologies discussed in this paper the reader is referred to the bibliography

A. Plume Delineation

Plume delineation is the step in which the amount, nature, source, and location of the ground water pollution is characterized. The information obtained in this step will not only help determine feasible cleanup strategies but may also help assess the possibilities of pretreatment or economic recovery. Types of Information needed for plume delineation include: physical/chemical characterization of the pollutant; information on transport and fate; toxicity and health risks; areal extent, depth, amount of pollutant; physical/chemical characterization of the waste; variability of the wastes; time factors; and previous waste disposal practices.

B. Hydrogeologic Characteristics

Understanding the hydrogeologic characteristics of a site is essential for a successful aquifer restoration program. In essence, this step is really a characterization of the subsurface which is where the problem exists. The subsurface characterization will serve two main purposes. First, a description of the hydrogeologic characteristics of the site allows for a better understanding of the magnitude of the problem. Because the problem is underground one cannot see, feel, smell or taste the extent of the problem. A thorough hydrogeologic investigation will not totally delineate the limits of the problem, but it will aid in estimating what has happened to the pollutant in the subsurface. Second, a thorough hydrogeologic investigation will aid in determining feasible solutions to the problem. Information from this step will be used extensively in the plume delineation step. Some areas of needed information include: geologic setting and generalized soil profiles, soil physical/chemical characteristics, depth to ground water and bedrock, ground water flow patterns and volumes, recharge areas and

Table 2: Potential Sources of Information

Group I (problem specific)	Federal or state geological surveys, universities-libraries, geology and engineering departments, state health departments, property owner, county records, well drillers.
Group II (site specific)	Weather bureaus, state water resources boards, census bureaus, soil and water conservation districts, employment commissions, corporation commissions, 208 studies, Department of Agriculture, Forest Service.
Group III (other)	Medical libraries, state or federal environmental protection agencies, state attorney generals office.

rates, aquifer characteristics, existing monitoring well locations and procedures, and background water quality data.

C. Site Characterization

A description or characterization of the site of the problem is an important step. Because surface attributes of the site will indirectly affect the subsurface environment these attributes need to be identified. The characteristics include climatic information (precipitation, temperature, and evapotranspiration) and, location information (topography, accessibility of the site, site size, proximity to surface water, and proximity to population centers).

D. Water Use and Requirements

Determination of current water use and future requirements will aid in determining the criticality of the threatened ground water formation. Information needed includes current and projected future water use, current and anticipated water quality standards (including beneficial use and effluent standards), and costs of alternative water supplies.

E. Human Health Costs and Risk Assessment

An assessment of risks to human health associated with the polluted ground water is a necessary step. Having identified the toxicity and health hazards of the given pollutant during the plume delineation step one then needs to assess the actual potential for one of these events to occur. This step is essential in evaluating the do-nothing alternative. Information from this step will be used extensively later in the alternative evaluation procedure.

F. Land Use Patterns and Growth Projections

The objective of this step is to insure that potential restoration strategies do not become exercises in futility. Specifically, one does not want to spend millions of dollars cleaning up a particular problem that is just one of dozens facing an aquifer or will be negated by future ground water threatening activities. One needs to check if the proposed solution is in accordance with local land use patterns and growth projections.

G. Regulations and Institutional Constraints

A key step in any aquifer restoration strategy is to identify any institutional constraints and who enforces them. To date, a majority of states do not have regulatory agencies for ground water quality control and determining who is in charge may be somewhat of a problem. Identification of all constraints and enforcement agencies is necessary so that a proposed solution satisfactory to one group does not violate the standards of another group. This includes an understanding of the role of pertinent regulatory agencies; their standards, regulations and guidelines, and pending legislation.

H. Funding

Probably the biggest obstacle to be overcome in any aquifer restoration program will be funding. In simple terms, cleaning up ground water is a very expensive venture. Not only are the technologies expensive to implement and operate, but they are also difficult to design. If questions arise over who will foot the bill (as they often do), the cases wind up in litigation, thus adding to the expense and delaying their implementation. As one might guess, these delays only compound the problem and escalate the costs. A preliminary review of the availability of funds should most probably become the first step after identification of the problem. Based on the availability of funds, the scope of the analysis can then be decided. If funds are not available, the full blown engineering analysis and design will probably have to be foregone for a small scale aquifer management or policy analysis. Some of the funding issues include determination of responsibility, identifying matching funds, and securing private support.

Data Evaluation

The critical aspect of the information gathering step will be evaluating the quality of the information gathered. Kaschak and Nadeau (1982) list three issues to be concerned with once available information has been gathered as: how good is the data today; can an engineering solution be properly developed and designed; and will the data be defensible in court? Consideration of the age of the information, sampling and analysis protocols, and the chain of custody of the information can aid in assessing whether or not it is accurate and/or useful.

Data Needs

Having completed the gathering and evaluation of available information, the next step is to identify those areas where the search for information was unsuccessful. Kaschak and Nadeau (1982) identify this as the most difficult step, i.e., to decide what additional information is necessary to be able to identify and evaluate remedial alternatives without "studying the site to death". Information voids should be identified and categorized according to criticality or importance of the data, ease of availability, time required to gather the data, and costs of the effort.

After all the information gaps have been categorized under the above headings one needs to weigh the work, time, and cost requirements against the scope and funding of the study outlined previously. If the information gathering process alone will exceed the funding, the study may have to be abandoned, scaled-back, or re-directed.

DEVELOPMENT OF ALTERNATIVES

Definition of Goals

The term "restoration" seems to imply that any ground water remediation activity will attempt to return the aquifer to its original condition. Although desirable, this is not always feasible. Truly, the main decision to be made in any aquifer restoration program is what the "goal" of the program should be. The specific strategies to obtain these goals is dictated for the most part, by physical or monetary constraints.

This paper considers four different goals: prevention, abatement, cleanup, and restoration. Prevention, as the name implies, means that pollution is not allowed to occur. The context of "prevention" in this paper is taken to mean "not allowing pollutants to reach ground water". Abatement means "to put an end to". Hence, abatement of ground water pollution is the "cessation of pollutants moving into the ground water and the elimination of the movement of pollutants having already reached the ground water". Cleanup is taken to mean "elimination of the pollutant through removal and treatment or immobilization". Restoration will include those measures that attempt to return the aquifer to its original state. This most often will involve a cleanup strategy plus some recharge of fresh water. It should be noted that these goals are not totally independent of each other. More specifically, a truly effective "cleanup" strategy will include "prevention" and "abatement" steps also. Table 3 is a listing of the various strategies available for obtaining the above goals.

The definition of the goals of a ground water management strategy is not a totally subjective evaluation. In some instances, the feasible goals will be dictated by problem-specific conditions. It is therefore recommended that a review of the preliminary steps be undertaken prior to establishment of any goals.

Goals Identification Matrix

Figure 4 is a goals identification matrix. Listed down the left-hand side are the possible goals and along the top are some goal decision factors. Probably the best way to use the matrix is to become familiar with each box in the matrix. If one can become familiar with

Table 3: Currently Practiced or Proposed Aquifer Restoration Strategies for Chronic Pollution Problems

Goal	Strategy Type	Action
Prevention	Institutional Measures	1. Aquifer or effluent standards, effluent charges or credits, land zoning.
	Source Control	1. Source reduction or removal
		2. Optimum site selection
		3. Man-made control options
		a. Impermeable membranes
		b. Impermeable materials
		c. Surface capping
		d. Collector drains
		e. Interceptor trenches
Abatement	Waste Management	1. Modification of pumping
		2. Pressure ridges
		3. Pressure troughs
		4. Subsurface barriers
Cleanup	Waste Treatment and Disposal	1. Above-ground treatment
		2. In-situ methods
Restoration	Cleanup Plus Recharge	

Figure 4: Goals Identification Matrix

Management Strategy	Temporal Situation	Funding Costs	Water Use Requirements	Hydrogeological Characteristics	Areal Extent	Human Health Risks	Land Use Patterns
Restoration	Restoration is a possible goal when considering existing problems.	Restoration schemes are the most expensive management strategies. However, restoration will also have the added benefits of returning the aquifer to a beneficial use.	Restoration should be the primary goal when dealing with ground water that is or will be the main source of water supply for a given area.	Restoration is most feasible for shallow, unconfined aquifers of originally high quality water.	As the size of the problem increases the attractiveness of the restoration schemes decreases due to increased costs. Problems of regional nature most probably will be amenable to abatement measures.	If human health risks are high, restoration or cleanup should be given top priority if technically feasible. If not technically feasible, abandonment and development of new source should be considered.	Restoration and cleanup measures should not be given high priority in areas that are or will continue to be subjected to ground water quality stresses such as industrial waste disposal areas.
Cleanup	Cleanup is a goal when considering existing problems.	Cleanup strategies are expensive. Sometimes the aquifer can be returned to a beneficial use and there is also the possibility for economic recovery from certain pollutants.	Cleanup should be considered when the ground water serves a beneficial use other than human consumption such as agricultural or industrial purposes.	Cleanup measures are most feasible for shallow ground water sources, but do have some applicability to deeper, confined sources by removal and treatment.	Cleanup measures are not economically attractive for small, localized problems and do have economies of scale for larger problems. However, if the problem becomes extremely large, such as regional, these economies of scale disappear.	See above.	See above.
Abatement	Abatement can be considered when dealing with existing problems and can also be included as a safeguard for future facilities or anticipated problems.	Abatement strategies range from moderate to very expensive with little chance for economic recovery.	Abatement measures are usually employed to save the unpolluted portions of an aquifer while conceding the polluted portion as lost.	Abatement measures are most applicable to shallow sources with cessation being the most applicable abatement measure for deep resources.	The abatement measures to be employed are size specific and cover the whole range from very small, localized problems to large, regional problems.	For low to moderate health risks abatement measures can be employed to prevent further degradation of an aquifer.	Abatement measures are the most attractive alternatives for ground water pollution control in areas subjected to continued threats if anything at all is to be done.
Prevention	Prevention measures are only applicable to future facilities or anticipated problems	Prevention strategies range from low to moderately expensive with little chance for economic recovery.	Prevention measures should be applied to protect any currently used or potentially useable ground water resource.	No restrictions	Physical prevention measures are size specific. Some institutional measures are applicable on a regional level.	No restrictions.	No restrictions.

the limiting factors for each of the possible goals, selection of a feasible and obtainable goal will become an easier process.

Not all possible factors have been listed in Figure 4. The major factors most likely to influence the choice of any goals are listed. Each problem will have its own extraneous factors which will influence the selection of the specific goal. Figure 4 is to be used as a general guide.

Technology-Decision Factor Matrix

Having developed at least a preliminary goal for a particular problem, one can then move to the technology-decision factor matrix in Figure 5. If one enters the column labeled "Management Strategy" and reads down, the technology (technologies) that can achieve that goal can be identified. After identifying the feasible technology (technologies) one then reads across the rows for that technology to identify any factors that might limit the applicability of that technology. The end result of these two steps should be the identification of a series of technologies or technology combinations that are applicable to a particular problem. Further elimination of these technologies will come in the scope design.

Preliminary Screening

Having developed a preliminary list of feasible technologies one can then move into a preliminary screening process to narrow down the number of choices. The preliminary screening process will necessarily rely heavily on professional judgment, and include factors such as technical feasibility, public acceptance, and physical constraints.

Scope Design

Probably the best means of eliminating possible but non-feasible alternatives would be through the use of a scope design. The scope design is a small scale analysis of the proposed alternatives for preliminary estimates of size, costs, life expectancy, efficiency, etc. The scope design will rely on estimates or ball park figures for costs, etc., to generate a rough estimation for each of the proposed alternatives. The scope design should be less expensive, less time consuming, and inherently less accurate than a full blown engineering analysis. Therefore, alternatives that test out to be similar in costs should not be eliminated from further consideration. The objective of the scope design should be to eliminate the obviously too expensive or too land intensive alternatives.

Figure 5: Technology Decision Factor Matrix

	Management Strategy and Complementary Technologies	Temporal Situation	Pollutant Type	Areal Extent	Soils	Aquifer Characteristics	Site Characteristics	Regulations
Slurry Systems	Slurry walls can only be parts of overall containment or cleanup schemes. Slurry walls are [illegible] applicable as abatement measures, however, some sort of ground water control system is usually included. Slurry walls are also [illegible] applicable as prevention measures, but once again are usually used in conjunction with other measures.	Slurry walls are very versatile in that they can be applied to existing problems as abatement measures or they can be incorporated in the design of future facilities for prevention of ground water pollution. Slurry walls are probably not applicable to emergency situations such as spills.	Slurry systems are sensitive to specific pollutants, especially those of high ionic strength.	Slurry systems are more applicable to larger problems. Slurry systems become more economical as the "length to depth" ratio increases.	Slurry systems are applicable to most all soil types. However, in loose soils such as sand or gravel there can be significant losses of slurry which may make the system uneconomical.	Slurry systems are generally applicable to shallow (<150 ft.) aquifers.	Sites with general accessibility, moderate topographic relief, and a ready source of water are most desirable. Construction of slurry systems is an equipment intensive operation which requires large amounts of water.	Some construction procedures are patented and will require a license.
Grouting	Grouting is similar to slurry systems in that it will often require complementary technologies to accomplish containment or cleanup. Grouting can be individually applicable as an abatement measure.	Grouting is also a versatile technology in that it has wide applications to both existing and anticipated pollution problems. In addition grouting is being promoted as a procedure for containing emergency spills.	Grouts containing bentonite clay are subject to limitations similar to those for slurry systems. Additionally, chemical grouts are not successful in highly acidic or alkaline environments.	Costs for grout cutoff systems are high, hence they will be applicable to small localized areas of pollution.	Grouting is limited to granular types of soils that have a pore size large enough to accept grout fluids under pressure yet small enough to prevent significant pollutant migration before implementation. Grouting in a highly layered soil profile may result in incomplete formation of grout envelope.	Presence of high water tables and rapidly flowing ground water limits groutability due to dilution of grouts and rapid transport of contaminants.	Similar to those for slurry systems above.	Some grouting procedures are proprietary and some chemicals may be controlled under the Underground Injection Program.
Sheet-piling	Sheet-piling follows the guidelines of grouting and slurry systems in that its most practical applications will be for abatement and prevention of ground water pollution. However, the number of cases where sheet-piling will be the best technology is limited.	Sheet-piling is similar to grouting. Probably the most applicable situation will be as emergency measures for containment of spills.	Sheet-piles are generally corrosion resistant.	As the size of a project increases, sheet piling will become uneconomical because of high material and shipping costs.	Pile driving requires a relatively uniform, loose, boulder-free soil for ease of construction.	Sheet-piling will be limited to shallow (<100 ft.) aquifers	Similar to those for slurry systems except the operation is not water intensive.	
Impermeable Liners	Liners are usually placed on a site prior to the initiation of a given activity, hence they are most applicable as prevention tools. Liners themselves are not usually effective and are usually used in conjunction with surface water control, source control, or underdrain systems.	The applicability of liners to existing problems is limited in that it usually involves removal of the waste or polluted soil.	Some asphaltic and treated soil liners become more permeable upon exposure to leachates. Some synthetic liners show poor resistance to hydrocarbons.	Because installation of liners involves excavation and specialized construction, economies of scale occur for larger problems. However, if the size of the problem is more than 3 to 10 acres, liners may become uneconomical due to material costs.	Soils do not limit the application of liners, except when native clays are to be used as the liner. In this case the soils should be of sufficient impermeability and sufficient thickness.	Very high water tables may limit the use of liners in that they may cause the system to "float".	The site should be accessible to a variety of construction vehicles, including some specialized liner installation machines.	Some states now have regulations governing the in-place characteristics which a liner must possess.

Figure 5 (continued)

	Management Strategy and Complementary Technologies	Temporal Situation	Pollutant Type	Areal Extent	Soils	Aquifer Characteristics	Site Characteristics	Regulations
Interceptor Systems	Interceptor systems can be employed for cleanup, abatement or prevention of ground water pollution. However, in all cases a complementary technology is required, usually in the form of surface treatment and discharge.	When dealing with existing problems, interceptor systems will take the form of interceptor trenches, while anticipated problems are usually prevented by employing collector drain systems. There is some applicability of interceptor trenches to emergency spills involving floating hydrocarbons.	Interceptor systems are applicable to any pollutant that flows with or on top of the ground water.	Interceptor systems are feasible for small, localized pollution sources.		Areas with high water tables or high impervious soils or rock layers are desirable.	Because the collected water will need to be removed, treated, and discharged, the site should be readily accessible.	
Well Systems	Well systems are applicable to all management strategies (excluding prevention. Well systems in all cases require complementary technologies, usually surface treatment and discharge.	Well systems are applicable to both existing and anticipated problems and have been used to control emergency situations in certain cases.	Well systems are applicable to any pollutant that flows with or on top of the ground water.	Well systems are probably not economically feasible for small, localized pollution sources. Conversely, for large sources of pollution well systems may become uneconomical in that they by necessity draw in both polluted and non-polluted water.	Well systems require soils that readily transmit ground water and any associated pollutants.	Well systems are amenable to most aquifer types. However, they may not be ideal for extremely shallow aquifers (<3 m.).	Sites must be accessible to drilling equipment. Well systems usually will require monitoring and a receiving source for their discharge. If the removed water requires treatment the site should be accessible to or in the proximity of surface treatment facilities.	
Surface Water Control	Surface water control technologies are most often used as preventive measures but can also be used as part of abatement schemes.	Surface water control can be applied to existing problems as part of an overall abatement scheme and should be considered in the design of all future land disposal facilities.	Surface water control is applicable to most any pollutant, however, the possibility of gas production should be considered when designing "surface capping" measures for organic wastes.	No restrictions.	Surface water control measures are applicable to any soil. Surface capping becomes economical when there exists native clays readily available.	No restrictions	Regrading to minimize runoff is an important aspect. Hence areas with extreme topographic relief should probably be considered less desirable.	
Source Control Strategies	Source control measures are most applicable as preventive techniques. However, they are often incorporated as part of overall cleanup measures at uncontrolled sites.	Source control strategies are applicable to existing problems and should be included in the design of all future disposal facilities.	No restrictions.	No restrictions.	No restrictions.	No restrictions	Since most source control strategies will involve surface activities, the site should be readily accessible.	
Institutional Measures	Implementation of institutional measures will most probably be for the prevention of ground water pollution but could also be used as abatement measures.	Applicability to existing problems is probably minimal except for orders to cease a given activity. Widest application is for preservation of current high quality ground water.						

Iteration

With preliminary size and cost data generated from the scope design, one would then want to iterate through the procedure outlined above. Perhaps the data generated might indicate that all the possible alternatives exceed the funding available. In this case, one might want to redefine the goals of the ground water management strategy, and attempt to develop new possible technologies for achieving these modified goals. Similarly, one might have identified extraneous factors from the screening or scope design steps that might influence which technologies are feasible. The objective of the iteration step is to narrow down the list of proposed alternatives to those that are truly economically and technically feasible.

EVALUATION AND SELECTION OF ALTERNATIVES

Selection of a single alternative from the list of proposed alternatives should come from balanced consideration of technical, economic and environmental factors. The following sections will identify potentially useful tools for evaluating the economic, environmental and risk implications of aquifer restoration schemes. Key issues or unique aspects of these evaluations will also be discussed.

ECONOMIC EVALUATION

Economic evaluation of the proposed alternatives can follow the traditional procedure of itemizing all the costs for a given project, ammortizing these costs for the life of the project, developing some measure of the benefits of the project, and comparing these figures for each of the alternatives. A number of unique issues arise when considering an economic evaluation of ground water contamination problems.

The first major issue to be concerned with is comparison of alternatives on a common basis. Two alternatives may be projected to achieve the same result through radically different methods.

The second major issue to be concerned with is the cost items associated with alternatives. It is important that all cost items be identified. As an example of how large these lists can be, Lundy and Mahan (1982) provide a list of cost components for a well system in Table 4.

Bixler, Hanson and Langner (1982) note that cost items can be monetary and non-monetary, direct or indirect. In addition to the obvious direct monetary costs such as materials, equipment, etc., non-monetary costs must be included such as relocation costs, loss of revenues, decreased property values and others. It is important that

Table 4: Cost Components of Well Systems

Cost Component (K, O&M)	Cost Elements	Principal Factors Affecting Cost
Plume Delineation (K)	Soil borings Monitor wells Data analysis Laboratory analysis Reporting	Plume area & depth Complexity of hydrogeology
System Design (K)	Consulting fees Computer time	Complexity of hydrogeology Size of containment system
Well System (K)	Construction engineering Well construction Materials	Plume size Aquifer flux Transmissivity
Surface Infrastructure (K)	Access roads Power transmission Piping	Plume size Configuration of wells
Treatment Facility (K)	Construction engineering Treatment system	System discharge Composition/concentration of recovered water
Well System (O&M)	Pump operation (power) System maintenance	Aquifer flux/pumping depth Fluid corrosivity
Treatment Facility (O&M)	Chemicals Labor Power	System discharge Composition/concentration of recovered water
Monitoring	Sampling Analysis Reporting	Complexity of system

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Treatment Facility (O&M)	Chemicals Labor Power	System discharge Composition/concentration of recovered water
Monitoring	Sampling Analysis Reporting	Complexity of system

Lundy and Mahan (1982)

the list of cost items be complete and include all pertinent costs (Thorsen, 1981).

Another issue associated with economic evaluation of alternatives is that of developing a measure of the benefits of an alternative. Some benefits will be very difficult to assign dollar values to, for example, reduced health risks. Additionally, some benefits may be hard to assess, much less assign a price tag to as is the case with health risks.

The final and most important issue associated with economic analysis is the approach to be utilized. St. Clair, McCloskey and Sherman (1982) analyze the advantages and disadvantages of various approaches including; risk assessment, cost/benefit analysis, cost-effectiveness analysis, trade-off matrices, and sensitivity analysis. Utilizing the positive attributes of these approaches, St. Clair, McCloskey and Sherman (1982) have developed a framework for evaluating cost-effectiveness of remedial actions at uncontrolled hazardous waste sites.

In summary, it can be said that there exists no ideal methodology for economic evaluation of aquifer restoration strategies. The best approach is to develop a modified version of an existing methodology that is applicable to the problem of concern. The methodology utilized should have the following basic attributes: (1) it compares alternatives on a common basis; (2) it possesses some measure of assessing benefits; (3) it is comprehensive and considers all relevant factors; and (4) its results are not subject to bias and are replicable.

ENVIRONMENTAL EVALUATION

Each of the proposed alternatives must also be analyzed for its potential impact on the environment. There are a variety of approaches that can be used to assess these impacts including empirical assessment methodologies, interaction matrices, network analysis, checklists, and others (Canter, 1977). The purpose of this section is to point out the need for environmental impact assessment in aquifer restoration projects and to identify some unique issues associated with it.

The first unique issue to be identified in association with ground water cleanup activities is that some alternatives may represent "an irretrievable committment of natural resources", i.e. some alternatives may require that the aquifer remain permanently altered. This is especially true of the below ground technologies such as impermeable barriers (slurry walls, grouts), or the in-situ cleanup technologies. In essence, the environmental evaluation should give special emphasis to the fate of the subsurface environment.

Secondly, because the unique aspects of ground water remediation activities usually lie underground, the above ground consequences of the

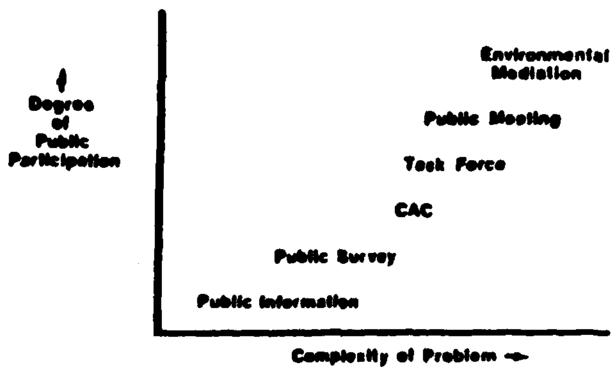

Figure 6: Six Levels of Public Involvement
(Freudenthal and Celender, 1982).

remedial action should be relatively easy to assess. More specifically, ground water remedial actions for the most part, do not represent large, land intensive undertakings. Depending on the technology employed, there will exist a potential to affect any of the environments (water, air, noise). However, the magnitude of these impacts will not be as great as for previously studied actions such as dams, power plants, highways, etc. There should exist ample information on related activities so that the assessment of the above ground impacts of ground water remedial actions becomes simple, straightforward and less time-consuming than the assessment of subsurface effects.

The last issue associated with environmental evaluations is the importance of public participation. Because of the recent attention afforded ground water pollution episodes by the media, the public has become ill-informed and frightened. It is desirable to avoid public hysteria in any project and this is especially true for aquifer restoration projects. Because ground water is a "hidden resource", improving the public understanding will be especially difficult. Careful planning and increased attention should be applied to the role of public participation in any ground water pollution environmental studies. Freudenthal and Calender (1981) note that public participation programs can promote conflict resolution by providing opportunities for individuals and opposing groups to explore compromise solutions. Figure 6 shows six levels of public involvement and it shows that public involvement grows with the complexity of the problem. Ground water contamination problems tend to be complex and as such, public participation should be anticipated to be high.

RISK ASSESSMENT

It is necessary to start this section of the report with an excerpt from Cornaby, et al. (1982):

> "The paramount concern is that no known general methodology is available for conducting overall environmental risk assessment, risk assessment that includes both humans and especially non-human or ecological receptors. In fact, the terminology in the literature is not always clear, suggesting that our views and knowledge of environmental risk assessment are still evolving."

This statement should serve as adequate notice that assessing the risks of aquifer restoration alternatives will not be easy.

Berger (1982) states that risk assessment has been defined as, "the identification of hazards, the allocation of cause, the estimation of probability that harm will result, and the balancing of harm with benefit". Moreover, Berger (1982) states that selecting an effective remedial technique involves the balancing of the need to contain contaminants within acceptable levels against the costs associated with the cleanup measures. St. Clair, McCloskey and Sherman (1982) state

Table 5: Sources of Information for Each of the Rating Factors

Rating Factor	Sources of Information
Receptors	
Population within 1000 feet	• Local housing officials or census officers • Current topographic maps or aerial photos
Distance to the nearest drinking-water well	• Information obtained from knowledgeable sources such as Public Health Departments, water supply companies, well drillers, residents
Distance to nearest off-site building	• Local housing officials or census officers • Current topographic maps or aerial photos
Land use/zoning	• Land use or zoning maps • Aerial photos
Critical environments	• National Wildlife Federation and other national environmental groups • State and local environmental groups • U.S. Fish and Wildlife Service • State departments of Fish and Game
Pathways	
Evidence of contamination	• Information obtained from knowledgeable parties
Level of contamination	• Information obtained from knowledgeable parties
Type of contamination	• Information obtained from knowledgeable parties
Distance to nearest surface water	• USGS topographic maps or reports • Maps and reports from State or local Highway Departments or from universities or state geological surveys
Depth to groundwater	• USGS water supply papers, ground water bulletins and geologic reports • Local well drillers, water suppliers, and universities (geology departments)
Net precipitation	• NOAA annual weather summaries • General precipitation and evapotranspiration maps
Soil permeability	• USDA Soil Conservation Service county maps and reports • USGS soil maps and reports
Bedrock permeability	• USGS water supply papers, ground water bulletins and geologic reports • Local well drillers, water suppliers, and universities (geology departments)
Depth to bedrock	• USDA Soil Conservation Service county maps and reports • USGS soil and geologic maps and reports

Table 5 (continued)

Waste Characteristics	
Toxicity	• *Hazardous Properties of Industrial Materials* by N. I. Sax • *National Fire Protection Association's Guide on Hazard Materials* • *Registry of Toxic Effects of Chemical Substances*
Radioactivity	• Information obtained from knowledgeable parties
Persistence	• Partition Coefficients (see "Partition Coefficients and Bioaccumulation of Selected Organic Chemicals," *Environmental Science and Technology*, Vol II, No. 5, May 1977, p. 475.)
Ignitability	• *NFPA Guide* • *Lang's Handbook of Chemistry*
Reactivity	• *NFPA Guide* • Proposed RCRA Regulations, *Federal Register, December 18, 1978.*
Corrosiveness	• Information obtained from knowledgeable parties
Solubility	• *CRC Handbook of Chemistry and Physics* • *Lang's Handbook of Chemistry* • *Merck Index* • *Handbook of Environmental Data on Organic Chemicals*
Volatility	• *CRC Handbook of Chemistry and Physics* • *Lang's Handbook of Chemistry* • *Handbook of Environmental Data on Organic Chemicals*
Physical state	• Information obtained from knowledgeable parties
Waste Management Practices	
Site security	• Information obtained from knowledgeable parties
Hazardous waste quantity	• Information obtained from knowledgeable parties
Total waste quantity	• Information obtained from knowledgeable parties
Waste incompatibility	• *Federal Register Vol. 45, No. 98, May 19, 1980, p. 33258*
Use of liners	• Information obtained from knowledgeable parties
Use of leachate collection systems	• Information obtained from knowledgeable parties
Use of gas collection systems	• Information obtained from knowledgeable parties
Use and condition of containers	• Information obtained from knowledgeable parties

Kufs et al. (1980)

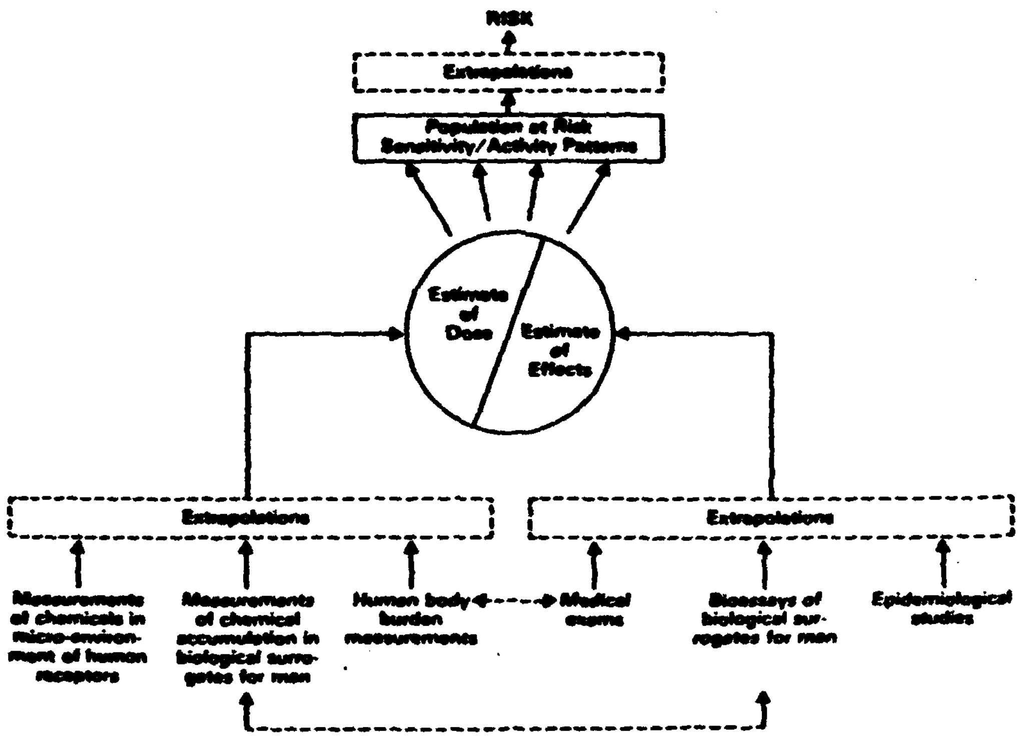

Figure 7: Extrapolations Required in Determining Risk (Schweitzer, 1981).

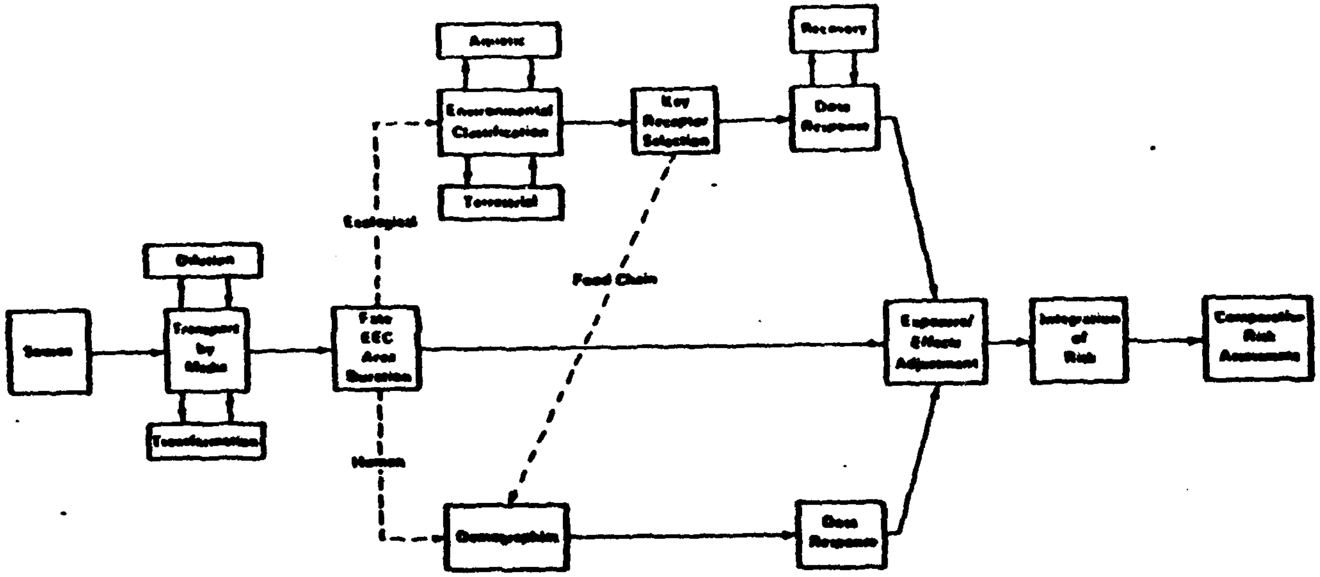

Figure 8: Overall Environmental Risk Assessment Scheme (Cornaby et al., 1982).

Table 6: Comparison of Techniques

Technique	Decision Making Criteria	Locus of Wisdom	Principal Assumptions	Decision Attributes	Data Requirements Possible
Formal Analysis •Benefit/Cost Analysis	Economic optimization	Formalized intellectual processes	•Man is or should be a rational economic maximizer •Decisions should be purely objective	Anything which can be converted to money	•All significant economic events & consequences •Accurate probabilities & magnitudes for each
•Decision Analysis	Utility optimization	Formalized intellectual processes	•Man is or should be a rational utility maximizer •Decisions should use decision makers value judgments	Anything; any number	•All significant events & consequences •Accurate probabilities & magnitudes for each
Comparative Analysis •Revealed Preference	Preservation of historical balance	Societal decisions during recent past	•Past decisions were essentially optimal •Little or no change in circumstances	Risk only	•Current risk •Historical risk
•Expressed Preference	Current preference	Societal decisions now	•Public understands & has well articulated preferences	Risk only	•Current risk •Current preferences
•Natural Standards	Biological wisdom	Long term species survival	•The optimal level of exposure to pollutants is characteristic of conditions during species evolution	Risk only	•Current risk •Risk magnitudes during geologic time
Professional Judgment	Professional judgment	Intuitive intellectual processes	•Professionals understand & have well articulated preferences • Professionals always exercise free will	Anything but limited number	Almost anything

Ess and Shih (1982)

Table 7: Technique Strengths and Weaknesses

Technique	Strength	Weaknesses
Formal Analysis		
Benefit/Cost	•Systematic •Ease of review •Handles all decision dimensions	•Discounts attributes which cannot be readily converted to economic terms •Large data requirements •Cannot handle subjective value judgements
Decision Analysis	•Systematic •Ease of review •Flexible •Handles all decision dimensions •Incorporates decision maker's judgment •Handles uncertainty well	•Large data requirements •Cannot handle public perceptions of risk
Comparative Analysis		
Revealed Preference	•Establishes absolute limits •Incorporates historical experience	•Past decisions often were not always optimal •Circumstances changing rapidly •Disaggregated historical baseline hard to establish •Does not address whole decision •Subject to inherent limitations of society and its citizens
Expressed Preference	•Establishes absolute limits •Allows for widespread public involvement	•Dependent on ability to get unbiased survey •Public does not always understand or have a preference •Does not address whole decision •Subject to inherent limitations of society and its citizens
Natural Standard	•Establishes absolute limits •Not subject to limitations of society	•Many of today's pollutants did not exist before •Does not address whole decision •Geological time baseline hard to establish •Does not allow for tradeoffs
Professional	•Handles all decision dimensions •Flexible •Easy to implement •Well established	•Hard to impossible to review •Bias due to employer •Stretched intuitive & cognitive skills can lead to erroneous judgements •Professionals appear to be losing public support

Ess and SHih (1982)

that "a risk assessment involves the definition of the risks to the environment and human health of continued pollution from a site" and "the most inexpensive remedial action that reduces the risk to an acceptable level could be considered the most cost-effective". Dawson and Sanning (1982) note that the objective of a remedial action is to reduce associated risks to an acceptable level".

The above statements are all straightforward yet they still yield some debateable issues. The most important question however, is how can the risks of aquifer restoration alternatives be assessed? There are two generally accepted approaches to risk assessment. The first approach is to take given criteria or standards for a contaminant and work backwards, utilizing intrinsic properties of the contaminant and aquifer, to develop a list of possible alternatives. The second approach is to analyze the effectiveness of various alternatives and compare their resultant concentrations with a given standard. No matter which approach is used, somewhere a "criteria" or "standard" or "acceptable level" is involved. These figures, for the most part, are non-existent. Dawson and Sanning (1982) outline a method for setting site restoration criteria by using air or water standards and working backwards with data on dilution potential and distribution characteristics. This methodology is dependent on criteria existing and knowledge of transport mechanics, which may not be available.

There have been a number of risk assessment techniques promoted for assessing the risk of hazardous waste sites. With slight modifications, some of these will be applicable to assessing different alternatives at individual sites. Unterberg, Stone and Tufuri (1981) outline such a procedure for assessing spill sites. Caldwell, Barrett and Chang (1981) have developed a ranking system for the release of hazardous substances. Nelson and Young (1981) discuss a location and prioritization scheme for future investigation of abandoned dump sites. Unites, Possidento and Housman (1980) describe the development of a site investigation manual. Kufs, et al. (1980) have developed a methodology for selecting sites for investigation based on their adverse environmental impacts. Berger (1982) describes a general methodology for assessing risks based on a similar approach as Kufs, et al. (1980). This methodology considers four characteristics: receptors, pathways, waste characteristics, and waste management practices. Table 5 is a list of information requirements for this methodology.

Schweitzer (1981) has developed a more specific methodology that is based on assessing sites by a chemical-by-chemical approach. The flow chart for this approach is in Figure 7. Figure 8 shows an approach to organizational aspects of environmental risk assessment developed by Cornaby, et al. (1982).

Lee and Shih (1981) have divided risk assessment techniques into three categories: (1) formal analysis, (2) comparative analysis, and (3) professional judgment. A comparison of the techniques is in Table 6 and their strengths and weaknesses are in Table 7.

Nisbet (1982) discusses some uses and limitations of risk assessments. Nisbet (1982) and Berger (1982) both point out that without detailed analytical monitoring programs, risk assessments can usually only produce a qualitative ranking of alternatives. Nisbet (1982) also points out that risk assessments are difficult to conduct and give uncertain results, because: (1) exposure is usually variable and poorly characterized; (2) toxicity information is hard to extrapolate to humans from animals; and (3) ground water transport mechanics are often unknown making the population at risk difficult to estimate.

Kos and Shih (1981) have identified the desired capabilities of any assessment methodology to be:

1. Means to provide estimates of risk probability.

2. Procedures to facilitate systematic thinking.

3. Processes which allow for the incorporation of inputs from multiple individuals and disciplines.

4. Easy to review.

In summary, risk assessment could be the most difficult aspect of evaluating ground water pollution cleanup alternatives. The problems to be encountered stem from the fact that most of the needed information for any comprehensive methodology will not exist. The use of estimations in any methodology will limit its replicability.

The best approach to risk assessment will be to develop a methodology suited to the problem in question. Modification of the existing methodologies discussed previously is one approach. The best risk assessment methodology will be one that best utilizes available information and requires the least amount of estimated input.

Summary

The final step in the protocol involves weighing the economic, environmental and risk assessments appropriately and deriving an optimum solution. A large number and wide variety of decision-making tools are available for selecting an optimum strategy from a list of alternatives. This protocol gives no preference to any select methodology as they all have advantages and limitations. For further discussion of these methodologies, the reader is referred to Canter (1977).

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ANALYSIS OF GEOHYDROLOGIC DATA BY KRIGING

Ronald Schalla and Joseph L. Devary
Battelle, Project Management Division
Office of Hazardous Waste Management
HAPO Building, Fourth Floor
601 Williams Boulevard
Richland, Washington 99352

(509) 943-9847 and (509) 943-2954

ABSTRACT

Hydrologic characterization of hazardous waste sites is an expensive and challenging task. Making efficient use of field data in modeling subsurface flow and transport can help private firms and government agencies control costs by achieving better results. Often, conventional approaches to geohydrologic data processing (e.g., hand contoured maps) are too subjective to provide the most efficient and accurate use of the data.

The geostatistical interpolation technique, kriging, and an elementary streamtube hydraulic conductivity inverse algorithm have been successfully applied to characterize the flow system at a complex hazardous waste site. Kriging aided in identifying the need for additional field measurements, selecting optimal well locations, determining the effect of subjective inferences (by geohydrologists) on the groundwater flow system, establishing data validity, and producing "best-fit" contour plots from irregularly spaced field measurements. Subsequent field work and the numerical modeling of flow and chemical transport confirmed the value of the geostatistical efforts.

INTRODUCTION

Making efficient use of field data to characterize the hydrogeologic systems at hazardous waste sites can help private firms and government agencies control costs and achieve better results. Kriging and inverse methods are more objective than subjective hand-interpolation of data by a geohydrologist. These objective methods have been applied to a multiphase remedial investigation for a government agency. The site hydrology, consists of a heterogeneous, anisotropic, multilayered groundwater system. Because of the complexity of the groundwater system, the objective techniques proved to be very beneficial for interpretation of irregularly distributed geohydrologic data. However, the insight and judgement of the geohydrologists were needed to interpret the relationship of geohydrologic parameter trends to patterns in the geologic fabric, to provide explanation of data anomalies identified by kriging, and to extrapolate parameter surfaces where little or no data existed. Similar findings have been reported in other studies (Orr and Dutton, 1983; and Devary, 1983).

AD-A148 194 PROCEEDINGS OF THE ENVIRONMENTAL SYSTEMS SYMPOSIUM 4/4
(13TH) HELD AT BETHESDA MARYLAND ON 20-22 MARCH 1984
(U) AMERICAN DEFENSE PREPAREDNESS ASSOCIATION ARLINGTON
UNCLASSIFIED VA 22 MAR 84 F/G 13/2 NL

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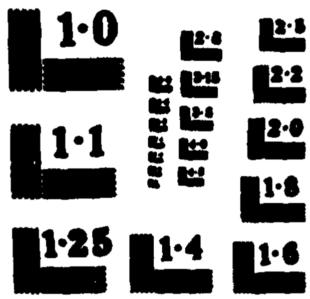

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The focus of this paper is on the evaluation of geologic and geohydrologic data using geostatistical tools. Topics which are discussed include:

- a kriging methodology for developing geohydrologic surfaces and evaluating the reliability and utility of field data;
- a stream tube hydraulic conductivity inverse technique for developing permeability and transmissivity distributions;
- the characterization of the groundwater system at a hazardous waste site using kriging, inverse, and conventional methods; and
- some concluding statements about the advantages and limitations of kriging and other computational techniques.

The section pertaining to characterization of the groundwater system includes a description of the importance of these techniques.

Kriging

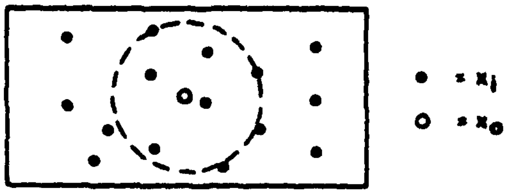
Kriging is a geostatistical technique that can be used to estimate a surface from spatially-distributed data. It was developed in the early 1960's primarily by the French mathematician George Matheron to solve mining estimation problems. In the last several years geohydrologists and groundwater modelers have utilized geostatistical techniques to analyze geohydrologic field data (Delhomme, 1976; Gambolati and Volpi, 1979; and Devary and Doctor, 1982).

Kriging is a statistically-based interpolator of irregularly spaced data. To krige an estimate of a variable (e.g., potentiometric head), at a particular location (x_o) where no field measurement is available, the following steps are required. For simplicity, it is assumed that x is a two-dimensional vector in a Cartesian plane.

1) Select the boreholes (with data) nearest the location to be estimated; typically, between eight and sixteen neighboring boreholes are used in the interpolation procedure. Let H_1, H_2..., H_n denote those measured values (Figure 1) which are assumed to be the realization of a stochastic process, H).

2) Determine the weights (i.e., the kriging weights) to be used for the averaging process; the kriging weights depend on the <u>drift</u> (overall trend) of the data and the <u>covariance</u> (variogram or generalized covariance) that corresponds to data fluctuations superimposed on the drift. Drift can be constant, linear, or quadratic. Letting $\lambda_1, \lambda_2, \ldots, \lambda_n$ denote the kriging weights. The kriging estimate at x_o is given by:

$$H^*(x_0) = \sum_{i=1}^{n} \lambda_i H_i$$



$$H^*(x_0) = \sum_{i=1}^{n} \lambda_i H_i$$

FIGURE 1. Kriging Estimate at Point x_0

3) The variance of the kriging error corresponding to the kriging estimation error, is calculated by using the kriging weights and covariance:

$$\sigma^2 (H^*(x_0) - H(x_0)) = K(o) - 2 \sum_{i=1}^{n} \lambda_i K(x_i, x_0) +$$

$$\sum_{i=1}^{n} \sum_{j=1}^{n} \lambda_i \lambda_j K(x_i, x_j)$$

where $K(x_i, x_j)$ is the generalized covariance evaluated at positions x_i and x_j; note: $H_i = H(x_i)$.

The kriging weights are selected to minimize the kriging estimation error variance $\sigma^2 (H^*(x_0) - H(x_0))$.

A full discussion of kriging theory may be found in Matheron, 1973; and Journel and Huijbregts, 1978.

The unbiased, minimum variance properties of kriging imply that the maximal amount of information is extracted from the geohydrologic field data. Also, a statistical quantification of the estimation error is established by using the error variance.

The statistical quantification of estimation error allows a geohydrologist or modeler to:

1) Establish data validity by comparing observed and predicted values; differences greater than 3 standard deviations (3σ) indicate potentially invalid data (with 99% confidence).

2) Objectively identify the utility or worth of gathering additional field measurements by examining σ.

3) Select optimal well locations according to the desired reduction in σ.

4) Evaluate subjective inferences by determining whether hand-drawn contour maps are within the 3σ error band of the kriged contour map.

In addition to producing contour maps by kriging and statistically quantifying the estimation error, sensitivity studies are beneficial to the process of selecting locations for new monitor wells. These studies require conditional simulations of sample values at potential observation locations to determine a plausible range of new observed values. Because selection of those observation locations may have significant impact on the conceptual and simulation model of the flow system, subjective judgement based on experience must also be applied even if only to serve as a check against kriging results.

Streamtube Hydraulic Conductivity Inverse Calculations

To accurately simulate contaminant transport, it is necessary to estimate the Darcian velocity field. Potentiometric head data are typically more plentiful and accurate than other types of geohydrologic data. Kriged potentiometric surfaces based upon head measurements are generally realistic interpretations of the flow system. On the other hand, hydraulic conductivity measurements that are derived from pump tests often exhibit tremendous variability and very little spatial correlation with observed hydraulic gradients. Significant errors in calculated hydraulic conductivity usually result from media heterogeneities and the fact that pump tests do not usually stress the system over a large enough area to be truly representative of macro-scale flow.

Researchers have resorted to "inverse techniques" to infer realistic hydraulic conductivity distributions from available potentiometric head and hydraulic conductivity data (Chavent, 1975; Cooley, 1977; Neuman, 1973 and 1980; Neuman and Yakowitz, 1979; Wilson and Dettinger, 1978; Wilson et al., 1979; and Nelson, 1960).

The inverse technique which we have used was designed by Stallman (1956), Nelson (1960 and 1961), Cearlock, et al., 1972), and Rice (1983), and involves scaling a known hydraulic conductivity value along a streamtube according to the convergence or divergence of flow. The approach requires a digitized potentiometric head surface to generate a flow net and a known hydraulic conductivity value for each streamtube. This approach is ideal for preliminary site characterization activities because a numerical groundwater flow model is not required. The basis of the method is as follows:

For systems in which two-dimensional flow predominates, the transmissivity, T, can be defined as:

$$T = D \times K \tag{1}$$

where D is the thickness of the saturated zone and K is the depth-average hydraulic conductivity. Darcy's Law yields:

$$q = -K(\text{grad } h) \tag{2}$$

where q is the specific discharge velocity, K is the hydraulic conductivity, and grad h is the hydraulic gradient. The discharge, Q, passing through a streamtube of cross-sectional area A is given by:

$$Q = -KA \frac{dh}{ds} \tag{3}$$

where s denotes the distance along the streamtube.

The discharge, Q, may be estimated by:

$$Q = -K \times (Wd) \times \frac{h_1 - h_2}{L} \tag{4}$$

where h_1 and h_2 are the potentiometric head values separated by a distance L along the streamtube, d is the streamtube depth, and W is the streamtube width.

Thus, if the hydraulic conductivity is known in one element of the streamtube, then the flux, Q, through the streamtube may be evaluated. Because mass must be conserved and the dimensions (d, W, and L) and head drop ($h_1 - h_2$) are known, the hydraulic conductivity along the streamtube may be inferred.

The streamtube inverse approach does not require a finite element or finite difference groundwater model as do other indirect approaches (Cooley, 1975; Neuman, 1973 and 1980; Neuman and Yakowitz, 1979; Wilson and Dettinger, 1978; and Wilson et al., 1979). However, the results of the streamtube inverse analysis should be considered preliminary and used only in initial site characterization studies. The inferred hydraulic conductivity distribution via this method is an ideal starting point for an indirect inverse flow model calibration procedure.

Flow System Characterization

The groundwater sources for the region encompassing the site were grouped into four layers: 1) silt and clay forming an aquitard (shallow system), 2) sand/gravel, 3) fractured bedrock, which along with Layer 2 comprises the aquifer (deep system), and 4) unfractured bedrock forming a lower confining layer. The groundwater flow and transport activities involved calibrating a three-dimensional finite-element model to simulate flow in the upper three layers. The geostatistical activities were concentrated on the aquifer where the contamination was most widespread, and therefore, the majority of monitoring wells (50-deep system vs 24-shallow system, as of April 1982) were bored into this deep system. Although a realistic potentiometric surface was kriged for the shallow system, only the work on the deep system is discussed here.

The left side of Figure 2 contains a plot of locations for wells bored into the deep hydrostratigraphic unit (50 wells) and a hand-drawn contour map of potentiometric head (April, 1982) as interpreted by the project geohydrologist. The potentiometric surface generally conforms to the topography with a convergence of flow along the eastern site boundary. Geostatistical data analysis techniques were applied to evaluate the hand-interpreted potentiometric surface and help select additional well locations for the next phase of drilling.

The validity of the April, 1982, potentiometric data was checked first. This involved deriving kriged estimates of potentiometric head at existing well locations using head measurements from surrounding wells. The kriged estimate utilized the eight closest neighboring wells using a constant drift (order = 0) and a linear generalized covariance, $K(h) = -1.0\ h$ where h represents the distance between wells. Thirteen data errors were discovered that were attributed to transcription errors and incorrectly-surveyed well locations, and two wells were assigned to the wrong hydrostratigraphic unit.

The right side of Figure 2 contains a contour plot of the kriged potentiometric surface based upon the April, 1982, measured head data. This surface was generated using the eight nearest neighbors, a constant drift (order = 0), and a linear generalized covariance, $K(h) = -0.0361\ h$. The order of drift (0) and generalized covariance ($-0.0361\ h$) were selected using identification routines developed for generalized increment processes (Matheron, 1973).

The hand-interpreted surface and the kriged surface (Figure 2) have the same general southeasterly flow characteristics, however, the two surfaces do not agree in a number of areas. The primary reasons and areas of disagreement between the geohydrologist's hand-drawn potential surface and the kriged version are:

- the lack of head data which resulted in head differences of up to 4 meters between the two versions in the areas east and south of the site boundary;
- the geohydrologist's hypothesis that a highly permeable, buried paleo-channel acts as a conduit to handle the interpreted flow convergence along the eastern boundary; and

- the geohydrologist's assumption that topographic highs represented structural highs for all layers and this, in turn, should be reflected by head potential highs along the south ridge, north ridge, north hill, and east of the site boundary.

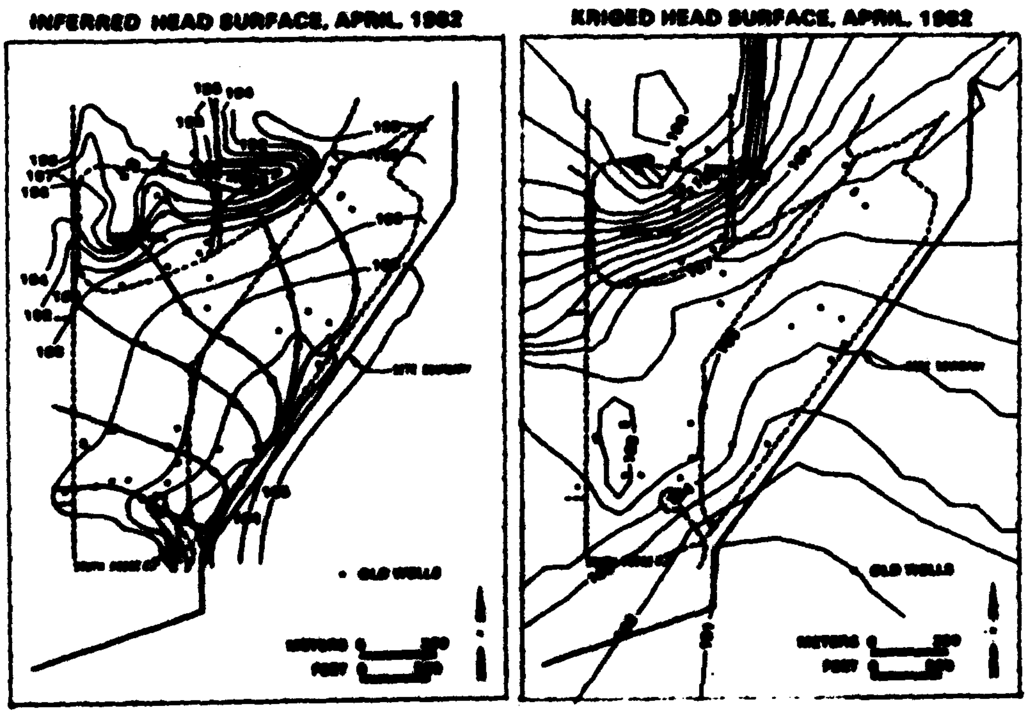


FIGURE 2. Hand-Drawn (Left Side) and Kriged (Right Side) Potentiometric Contour Map of the Deep System (April, 1982) and the Monitor Wells Used (Potentials in Meters Above Mean Sea Level)

Based on the differences between the kriged and interpreted surfaces, areas having kriged uncertainty greater than 1 meter, and the need for accurate characterization of contaminant plumes, 10 new wells were installed tapping the deep system. Following completion of the wells, a set of stabilized potentiometric measurements was collected in March, 1983, that included the ten new wells of the deep stratigraphic unit (Figure 3, right half). The differences between the April, 1982, (left half of Figure 3) and March, 1983, (right half of Figure 3) kriged potentiometric surfaces are listed below:

- The March, 1983, kriged surface was significantly smoother and more regular in the north hill area because of the new well and reclassifying several wells which proved to be interconnected with the deep system.

- The flow convergence was more clearly delineated in the March, 1983, kriged surface because of inclusion of a recently discovered off-site well (not shown) one-half mile east of the site.

The results of the new geohydrologic data and second kriged potential surface indicates:

- flow convergence does occur along the eastern site boundary as inferred by the geohydrologist; and

- a highly permeable, buried paleochannel probably exists along the eastern boundary (this was confirmed during subsequent field studies).

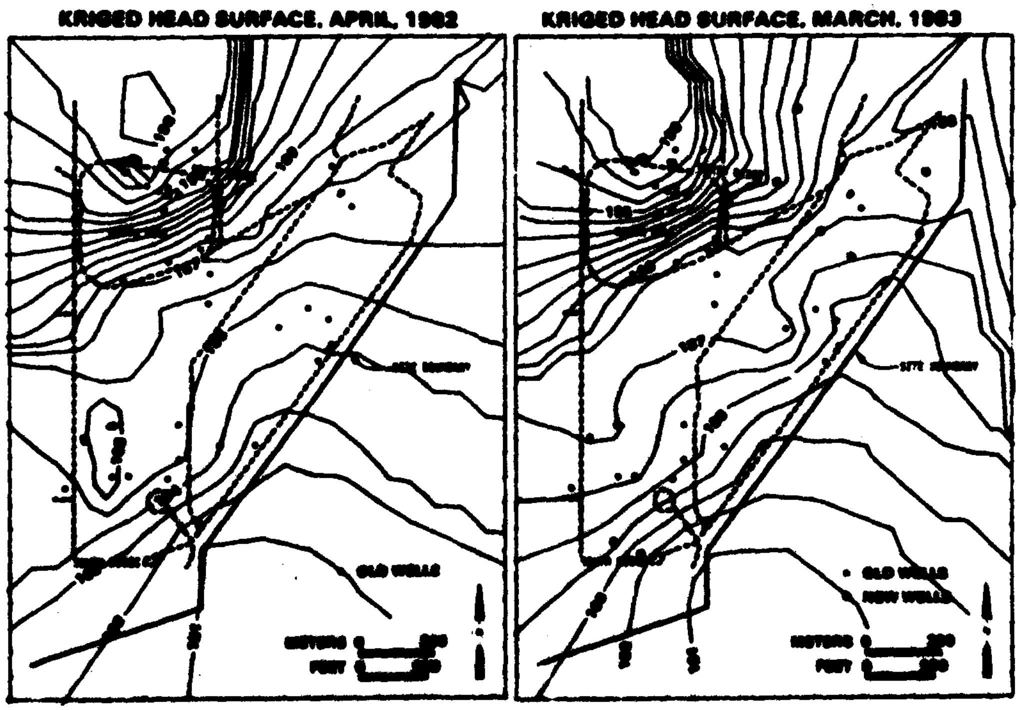


FIGURE 3. Comparison of April, 1982, (Left Side) and March, 1983, (Right Side) Kriged Potentiometric Surfaces with Locations of New Monitor Wells (Right Side) (Potential Contours in Meters Above Mean Sea Level)

In the above off-site area where data was lacking or scarce, the geohydrologist predicted the potential surface more accurately than kriging. The extrapolation of the probable potential surface was based on topography, on-site data, and off-site geologic data.

On-site where data is adequate, kriging proved to be superior because it is not biased, that is, it does not take into account the possible effects of topography or geologic inference as does the geohydrologist. The field data showed that although the geohydrologist correctly predicted the fractured bedrock surface (top layer 3) on the north hill and ridge, he overestimated the influence of the physiography and geologic fabric on the head potential and consequently groundwater flow direction. The two new wells on the south ridge confirmed that groundwater flows through the ridge and is not deflected around it as the geohydrologist predicted. This flow through the ridge occurs because the bedrock surface does not conform to the surface topography unlike other topographic highs in the study area. This last point is important to the design of a remedial action plan since contaminant sources are believed to be located in the southwestern corner of the site.

The next step in system characterization was to determine a hydraulic conductivity distribution that would conform to the flow-net derived from the March, 1983, kriged potentiometric surface using the VTT flow code (Bond, 1981). The left half of Figure 4 contains a kriged contour plot of the transmissivity data that had been derived from pump tests. The transmissivity data showed over four orders of magnitude of variability (range = 0.01 - 550 m^2/d) with very little correlation between transmissivity values and the flow-net. In order to be physically realistic (conserve flow), transmissivity values needed to be high in regions of low hydraulic gradient and low in regions of high hydraulic gradient.

To remedy the situation, the streamtube hydraulic conductivity inverse technique was applied to the kriged flow-net. The observed transmissivity values from on-site wells and estimated values from off-site wells in the 10-35 m^2/d range were used as initial values for six streamtube analyses for the region. No recharge or discharge was assumed along the streamtubes, and a uniform depth for the deep stratigrahic unit was specified. The inferred transmissivities along these six streamtubes were kriged to the entire region using six-point neighborhoods, constant drift (order = 0), and linear generalized covariance, $k(h) = -1\ h$. The inferred transmissivity distribution is presented in Figure 4, the right side; the six streamtubes that were used to characterize the region are also indicated.

The hydraulic conductivity distribution for the deep aquifer was then derived from the inferred transmissivity surface by dividing the transmissivity values by the aquifer thickness. This inferred hydraulic conductivity surface served as the basis for the first simulation runs of three-dimensional groundwater flow model. Utilizing the inferred hydraulic conductivity distribution for the deep unit and regional determinations of boundary flux, recharge, solute processes, and observed properties of other layers, the models used to predict flow, and transport were calibrated with only minor adjustments to the permeability field. The accuracy and calibration time saved demonstrates the usefulness of kriging and an elementary streamtube inverse technique to determine the hydraulic conductivity distribution.

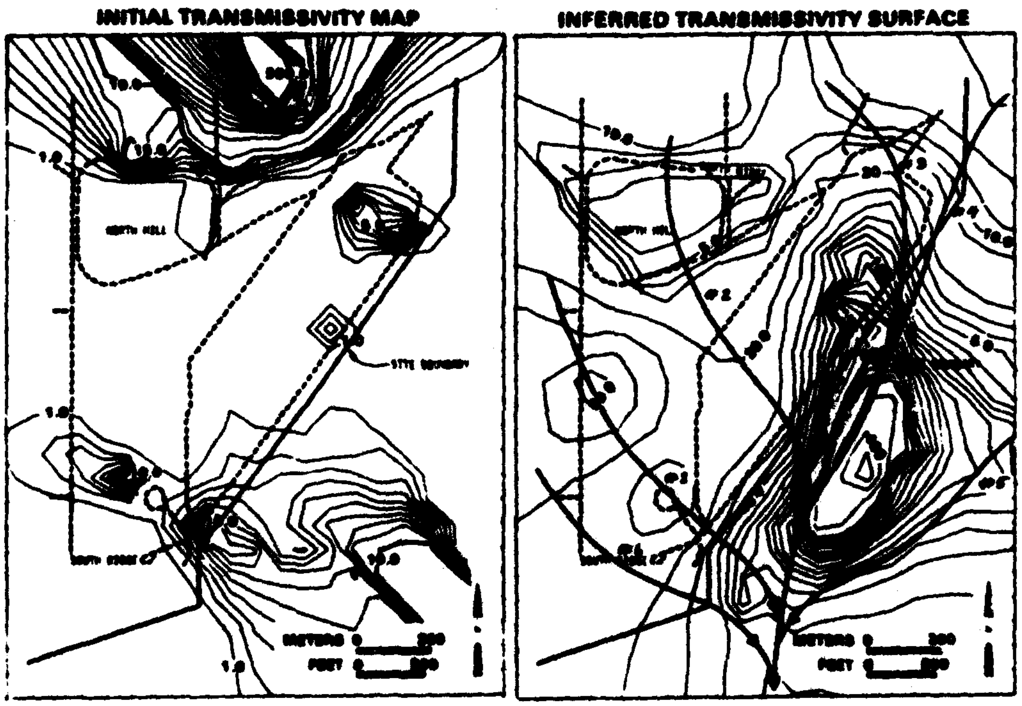


FIGURE 4. Comparison of Two Kriged Transmissivity Surfaces, Utilizing Existing Data Points (Left Side) and Streamtube Inverse Technique (Right Side) (Contours in Meters Squared per Day)

CONCLUSIONS

Because characterizing the spatial extent of contamination is such an important aspect of a site characterization study, kriging and its associated inverse technique are essential to determining monitor well placement and sufficiency, evaluating data validity, and performing sensitivity studies.

Some of the important benefits that kriging offers for processing geohydrologic data are:

- objectively and quantitatively identifying the need for additional field measurements to reduce data uncertainty to acceptable levels;
- selecting optimal well locations for defining the flow system, thus eliminating unnecessary monitor wells;
- providing objective feedback to determine the value of subjective inferences made by geohydrologists;
- establishing data validity;
- producing "best fit" contour plots from irregularly spaced field measurements;
- reducing the time and cost required to update computer simulation model surfaces as new data are required; and
- producing a mass-conserving hydraulic conductivity field in conjunction with the inverse technique.

Underlying all these potential benefits of kriging to geohydrologic site investigation is the fact that kriging alone cannot perform miracles. It is absolutely essential that experienced geogeohydrologists be involved with the geostatistician during the kriging analysis to provide additional site-specific information that kriging cannot assimilate. Kriging is simply an empirical technique to determine spatial interpolation; used with expert geohydrologic judgement kriging becomes a very powerful tool for site characterization.

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CARL M. ADEMA
DAVID TAYLOR NAVAL SHIP R&D
MECHANICAL ENG
CODE 2834
ANNAPOLIS MD 21106

W. JOSEPH ALEXANDER
RESEARCH TRIANGLE INSTITUTE
SR RSCH HYDROGEOLOGIST
P O BOX 12194
RSCH TRIAGLE PT NC 27709

DR. K. P. ANANTH
MIDWEST RESEARCH INSTITUTE
AREA MRKTG DIR
1750 K ST NW. STE 250
WASHINGTON DC 20006

DONALD A. BARBOUR
NUCLEAR METALS
2229 MAIN ST
CONCORD MA 01742

SUSAN G. BARISAS
ARGONNE NATIONAL LAB
ENV ENGINEER M/S 3C
9700 S. CASS AVE BLDG 362
ARGONNE IL 60439

CAPT RICHARD BREWER
USAF
CMD BIOENVIRONMENTAL ENG
HQ AF SYS CMD/SGPB
ANDREWS AFB DC 20334

BRIAN BURGHER
JRB ASSOC
8400 WESTPARK DR.
MCLEAN VA 22102

MARY-BERT CARMER
V.J. CICCONE & ASSOC.
14045 JEFFERSON DAVIS HWY
WOODBRIGHT VA 22191

JAMES A. CARRAZZA
USA ARMAMENT RES & DEV CNTR
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RICH CHAPIN. P.E.
PRICETON AQUA SCIENCE
PROJ MGR. WASTE MGMT DIV
789 JERSEY AVE
NEW BRUNSWICK NJ 08902

DR VINCENT J CICCONE
V.J. CICCONE & ASSOC INC
PRESIDENT
SUITE 5.14045 JEFF DAVIS HWY
WOODBRIDGE VA 22191

RAY CLARK
DEH
CHF ENV OFFICE
BLDG 215
FT MCCLELLAN AL 36205

PAMELA G. CLEMENTS
NAVAL ORDNANCE STATION
ENV. PROTECTION SPECIALIST
CODE 0F3
INDIAN HEAD MD 20640

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PROJ DIR
4329 MEMORIAL DR. SUITE C
DECATUR GA 30032

ROBERT B. CRAIG. PHD
OAK RIDGE NATL LAB
INTERAGENCY RSCH COORDINATOR
P O BOX X.
OAK RIDGE TN 37831

RICHARD D. CUNNINGHAM
DEWBERRY & DAVIS
8401 ARLINGTON BLVD
FAIRFAX VA 22031

VAL R. DAIGA
MIDLAND-ROSS COMPANY
TID DIV. MGR-PGM MKTG
PO BOX 985 - 900 N WESTWOOD
TOLEDO OH 43698

COL. PETER S. DALEY
OFFICE SECRETARY OF DEFENSE
DIR. ENV. POLICY
PENTAGON. RM 4C916
WASHINGTON DC 20330

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WEST CHESTER PA 19380

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US ARMY
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DR DONALD K EMIG
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ASSISTANT SECRETARY
ROOM 3D333, PENTAGON
WASHINGTON DC 20301

JOHN T. ENSMINGER
OAK RIDGE NAT'L LAB
DIR. INFO CNTR COMPLEX
P O BOX X, BLDG 2001
OAK RIDGE TN 37801

MR G R ESKELUND
US ARMY, USAMERADCOM
ENVIRO & PETROLEUM TECH DIV
ATTN. DRDME-GS
FT. BELVOIR VA 22060

EMILIA V. ESTRADA
OLIN CORP.
PROJ ENGINEER
BADGER ARMY AMMUNITION PLANT
BARABOO WI 53913

COL. PAUL F. FALLON
USAF
CMD BIOENVIRONMENTAL ENG
HQ AF SYS CMD/SGPB
ANDREWS AFB DC 20334

MR JAMES T FERGUSON
TECHNOLOGY MKTG CONSULTANTS
PRESIDENT
PO BOX 289
MILLERSVILLE MD 21108

ROBERT T FLOWE
US ARMY CORPS OF ENGINEERS
HQUSACE DAEN-ECM
20 MASSACHUSETTS AVE NW
WASHINGTON DC 20314

IRVING FURSTEN
CONSULTING ENGINEER
15 LAUREL COURT
VERONA NJ 07044

GEORGE M. GIBBONS
ENGINEERING SCIENCE
STAFF ENGINEER
10521 ROSENHAVEN ST
FAIRFAX VA 22030

G. C. GRINER
GARDNER, CARTON & DOUGLAS
SUITE 1050
1875 EYE STREET, NW
WASHINGTON DC 20006

BAILEY GUARD
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WASHINGTON DC 20510

GREGORY V. GUSHAW
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MGR. ADV PROGRAMS
P O BOX 85608
SAN DIEGO CA 92138

J.E. HANSEN
BATTELLE NORTHWEST
MGR. PROGRAM DEVEL.
P O BOX 999
RICHLAND WA 99352

H DAN HARMAN, JR.
ENGINEERING SCIENCE INC
HYDROLOGIST, STE 590
57 EXECUTIVE PARK SOUTH, NE
ATLANTA GA 30329

WILLIAM HASSSELKUS
DARCOM
DRCIS-A
5001 EISENHOWER AVENUE
ALEXANDRIA VA 22333

RICHARD T. HEIDERSTADT
ECOLOGY & ENV., INC.
MGR. ENV SCIENCES
195 SUGG RD
BUFFALO NY 14225

JOEL HIRSCHHORN
US CONGRESS
SR. ASSOC.
OFFICE OF TECH ASSESSMENT
WASHINGTON DC 20510

JERRY HOLSINGER
ARMY LOG MGMT CNTR
USALMC
ATTN DRXMC-MR-D EMC
FT LEE VA 23801

J. BRUCE HOLT
ADPA
ROSSLYN CENTER, STE 900
1700 N. MOORE STREET
ARLINGTON VA 22209

DONALD JACOBS
SAXTON CORP
DR. ENV TECH & WASTE MGMT DIV
102 UNION VALLEY RD
OAK RIDGE TN 37830

[illegible] JACKSON
ADPA
[illegible] CAROLINE ST., NW
WASHINGTON DC [illegible]

[illegible]

S. JOHNSON
HAZ. MAT. TECH. CNTR.
EDITOR, HMTC UPDATE
P O BOX 8168
ROCKVILLE MD 20856

SHELDON D. KISER
USA GARRISON
VINT HILL FARM STATION
WARRENTON VA 22186

ROBERT KNOX
UNIV. OF OK
PROFESSOR
NORMAN OK 73019

KEN KOK
BATTELLE
ASSOCIATE SECTION MANAGER
505 KING AVENUE
COLUMBUS OH 43201

WALTER P LAMBERT
ROY F WESTON INC
MANAGER R7D
WESTON WAY
WEST CHESTER PA 19380

BARRY S. LANGER
JRB ASSOC
SR PROJECT MGR
1 SEARS DRIVE
PARAMUS NJ 27666

MICHAEL F. LARSON
NAVAL ORDNANCE STATION
CHEMICAL ENGINEER
CODE CE7
INDIAN HEAD MD 20640

LINDA J. LAY
NAVAL ORDNANCE STATION
CHEMICAL ENGINEER
CODE CE2
INDIAN HEAD MD 20640

ZOYC LUCE
HERMITE DIVISION WHITTAKER
VICE PRESIDENT, HUMAN RESOURCE
26116 SOLEDAD CANYON RD
SAUGUS CA 91350

C. REED MAGNESS
USA AMCCOM
ENVIR.TECH.DIV./ENVIR.SCIENTIS
DRSMC-CLT-I.CHEM. RES CTR.
APG MD 21010

PETER J. MARK
ROY F. WESTON, INC.
VICE PRESIDENT
WESTON WAY
WEST CHESTER PA 19380

JOSEPH E. MASTROIANNI
NSWC
SR. CHEMIST
INDIAN HEAD MD 20640

JEFF F. MATESON
MATESON CHEM CORP
PRESIDENT
1025 E MONGOMERY AVE
PHILADELPHIA PA 19125

HUGH MCGILLICUDDY
MCGILLICUDDY ASSOC
CONSULTANT
1730 M ST NW 515
WASHINGTON DC 20036

JOHN MCHARDY
HUGHES AIRCRAFT
SR STAFF ENGINEER
P O BOX 902
EL SEGUNDO CA 90245

WILLIAM J. MCNULTY
AEROSPACE CORP
MEMBER TECHNICAL STAFF
955 L'ENFANT PLAZA, STE 4000
WASHINGTON DC 20024

WALTER MIKUCKI
US ARMY CONSTRUCTION ENG
RESEARCH LABORATORY
CHAMPAIGN IL 61820

DR. TONY MOSCATI
SVERDRUP & PARCEL
MGR. HAZ WASTE SERVICES
8720 GEORGIA AVE
SILVER SPRING MD 20910

H.W. MUELLER
HUGHES AIRCRAFT CO.
P O BOX 902
2000 EAST EL SEGUNDO BLVD
EL SEGUNDO CA 90245

M.R. NATHAN
CRAWFORD AND RUSSELL
[illegible] ENVIRON ENG
P O BOX 1432
STAMFORD CT 06904

[illegible]
[illegible]
[illegible]
[illegible]
WEST CHESTER PA 19380

[illegible] R. NICHOLLS
[illegible]
[illegible] MGT
[illegible]
FORT DEVENS MA 01433

JOHN W. NOLAND
WESTON
SR PROJ MGR
WESTON WAY
WEST CHESTER PA 19380

KATHLEEN O'HALLORAN
US ARMY
ENV PROTECTION SPEC
HQDA DAEN-ZCE
WASHINGTON DC 20310

P.P. OUELLETTE
VERSAR
DIR CORP PLANNING
6850 VARSAR CENTER
SPRINGFIELD VA 22151

JOSEPH PIZZUTO
BATTELLE COLUMBUS LABS
505 KING AVE
COLUMBUS OH 43201

GARY POTTER
ROCKWELL INTERNATIONAL
777 SOUTH WADSWORTH
IRON GATE IV, STE 201
LAKEWOOD CO 80226

MAURICE PRESSMAN
BELVOIR R&D CENTER
LOG SUP LAB
STRBE-GS
FT BELVOIR VA 22060

R.P. RODGERS
OAK RIDGE NAT'L LAB
MANAGER
P O BOX X, 8-4-501
OAK RIDGE TN 37830

TORSTEN ROTHMAN
DYNAMAC CORP.
THE DYNAMAC BUILDING
11140 ROCKVILLE PIKE
ROCKVILLE MD 20852

EDWARD R. SALTZBERG
JRB ASSOCIATES
SR VICE PRESIDENT
8400 WESTPARK DR.
MCLEAN VA 22102

LYDIA E. SANCHEZ
NAVAL ORDNANCE STATION
CHEMICAL ENGINEER
CODE CE6
INDIAN HEAD MD 20640

DORIS E. SANDERS
JRB ASSOCIATES
PROJECT MGR
8400 WESTPARK DR
MCLEAN VA 22102

R. SCHALLA
BATTELLE
PACIFIC NORTHWEST LAB
P.O. BOX 999
RICHLAND WA 99352

MARY SEXTON
ICF, INC.
SUITE 950
1850 K STREET, NW
WASHINGTON DC 20006

TERRENCE A. SHANNON
PHOENIX SAFETY ASSOC., LTD
VICE PRESIDENT
P O BOX 545
PHOENIXVILLE PA 19460

WALTER M. SHAUB
NATL BUREAU OF STANDARDS
HEAD, EXPLOR FIRE RSCH GRP
B260 PLYMERS BLDG #224
WASHINGTON DC 20234

RALPH N. SHAVER
CHARLES T. MAIN
SR ENV PROJ MGR
PRUDENTIAL CENTER
BOSTON MA 02199

ARTHUR J. SHELTON
CHEM WASTE MGMT
OPERATIONS COORDINATOR
P O BOX 116
EMELLE AL 35459

RAJIV SINGH
EARTHTECH, INC.
MINING ENGINEER
6632 AMBERTON DR.
BALTO MD 21227

COL. MICHAEL SISK
DEPARTMENT OF ARMY
ASST FOR OCCUPATIONAL HEALTH
OASA, PENTAGON, RM 2E587
WASHINGTON DC 20310

WAYNE E. SISK
USA TOX & HAZ MAT AGENCY
ATTN DRXTH-TE-D
ABERDEEN PGRD MD 21010

FRANCIS J. SMITH
RAC
PROGRAM MANAGER
[illegible] OLD SPRINGHOUSE RD
MCLEAN VA [illegible]

RICHARD A. SMITH
[illegible] CORP.
[illegible]
[illegible] AVE SW, STE [illegible]
WASHINGTON DC [illegible]